HEALTHY RIVERS AND STREAMS
CITIZENS ADVISORY BOARD
Plaza 1 Meeting Room
530 E Main Street Aspen, CO
Feb 21, 2013 - 4 p.m.

4:00	**Public Comment**	
4:05	**Board Comment**	
4:10	**Additions/Deletions to Agenda**	
4:15	**Approval of Minutes** January 17, 2013	
4:20	**Funding Request - Aspen Village Metro**	Gary Beach
4:35	**Funding request - Aspen Airport Business Center Stormwater Project**	GR Fielding Pitkin Co Engineer
4:50	**The Lower Crystal River: Implications of the 2012 Snapshot Assessment and Opportunities for Collaboration**	Chelsea Congdon Brundige Public Counsel of the Rockies and Seth Mason S.K. Mason Environmental
5:05	**The Future of Instream Flows in Snowmass Creek:** **Implications of AMEC 2012 Report and Opportunities**	Tim McFlynn and Chelsea Congdon Brundige Public Counsel of the Rockies
5:20	**Draft Scope of Work for RFP** **Interactive web based mapping project**	
5:30	**Letter of Support** **RWAPA Invasive Species Program**	
	Staffing	
	Executive Session **West Divide Litigation** **Busk Ivanhoe Litigation** **RICD Litigation** **Stapleton Brothers Litigation** **C.R.S. 24-6-402 (4)(b)**	

Future Agenda Items
Joint Meeting with Open Space and Trails
Joint meetings with BOCC

Upcoming regular meeting dates
March 21
April 18
May 16

HEALTHY RIVERS AND STREAMS CITIZENS ADVISORY BOARD
Meeting Minutes
January 17, 2013
530 E. Main St Plaza 1
Aspen, CO 81611

Board members present: Lisa Tasker, Bill Jochems, Andre Wille
Greg Poschman, Rick Neiley, Ruthie Brown

Board members absent: None

Others present: John Ely, Lisa MacDonald

Public Comment - None

Board Comment - None

Additions/Deletions to Agenda - Staff requested the following additions to the agenda:
Executive Session to discuss West Divide litigation pursuant to CRS 24-6-402(4)(b)
Request for proposals presentation by Zach Purdue regarding the Crystal River interactive mapping project
Funding request by Billy Grange Improvements to the Grace – Shehi Ditch System
Aspen Village funding request

Ms. Tasker moved to approve the addition of the four items to the agenda. Mr. Neiley seconded the motion. The motion passed 6 to 0.

Approval of Minutes
Ms. Brown moved to approve the minutes November 15, 2012. Mr. Poschman seconded the motion. The motion passed 6 to 0.

Appointments of Chairman and Vice-Chairman for 2013
Bill Jochems volunteered to Chair the Board. Approval by unanimous acclamation.
Andre Wille volunteered to be the Vice-Chairman. Approval by unanimous acclamation.

Castle Creek Hydro Chairman Jochems asked if the Board needed to express itself in addition to prior communications with the City. The Board will discuss its position after the issue resurfaces later this year. Ms. Brown will keep the Board abreast of any movement.

City of Aspen Rio Grand Stormwater – John Ely discussed with the Board the appropriation of $43,000 to help with construction of the City's stormwater plan.
An item of concern is the stressed reach of the Roaring Fork. In Mr. Miller's report to this Board, the area at the kayak park, he called this area out as problematic because of the depletion of stream flow, because as the stream flows are going down, there is still water being diverted into the kayak course, and is otherwise degraded before making its way back into the channel.
Staff will contact Mr. Miller for a cost estimate to draft a management document that takes into consideration the health of the stream and needs of the park.

Board Renewals and New Member - The Board was updated on the status of Board renewals and new member application by the Board of County Commissioners. To date the BOCC had re-interviewed Lisa Tasker and Andre Wille and had interviewed three applicants for Steve Hunter's position along with 2 more upcoming interviews. The BOCC is expected to make a decision by January 22nd.

Staffing The Board discussed staffing issues and what a part time position may look like. Someone handle projects so the Board could see a more streamline flow approach of items that come to them. More detailed information with costs will be discussed at the next meeting. Chairman Jochems encouraged the Board to envision what a staff person would do for them.

Funding request by Billy Grange Improvements to the Grace – Shehi Ditch System Feasibility Study -_ Ken Ransford and Billy Grange

The Board considered a funding a request from Mr. Billy Grange to fund 25% of a feasibility study and design of improvements to the Grace - Shehi Ditch. This ditch is just upstream of the railroad trestle bridge that crosses the Roaring Fork River on the Rio Grande Trail, upstream of the Roaring Fork Club. The Colorado Basin Roundtable approved a grant application for 75% of the $54,000 study contingent upon the applicant raising the 25% matching funds or $13,500. Total study cost is $56,777 of which the applicant has contributed $2.777. The Board authorized the expenditure with conditions.

Mr. Poschman moved to approve the $13,500 request for the feasibility study with the conditions that the study address what is the effect on the river flow and ditch efficiency in low water time of year below the ditch and what are the wildlife enhancements. Mr. Wille seconded the motion. The motion passed 6 to 0.

Request for proposals presentation by Pendo Solutions regarding the Crystal River interactive mapping project Zach Purdue

Mr. Purdue presented ideas on how to visually depict to the general public via the Healthy Rivers and Streams website how current water diversion structures on the Crystal River and associated tributaries impact stream flow conditions and overall stream health. Newly proposed diversions can also be added to the initial scope of the project. While the info-graphic would include the mapped data, it would also include a number of other data and pictures to more completely depict the changes in the river system over a given time frame. The other data could include graphs and charts, photos, as well as textual narratives, all spatially defined, that create a more complete product for the viewer. The mapping system would be plugged into the website to more actively engage the user and have the ability to show additional data and media that could not be included on the info-graphic. The system would have standard functionality, allowing the user to toggle data layers on/off, query data layers, as well as include standard navigation tools. In a web-based map, we can then include richer media, such as videos and more extensive photo slideshows, all spatially defined. All data could be linked to a number of other sources to extend the information being presented.

Mr. Poschman moved to approve an expenditure of $800 for the creation of a request for proposals to be drafted by Zach Purdue for an interactive mapping website. Ms. Brown seconded the motion. The motion passed 6 to 0.

Aspen Village Metro District

The Board will consider the funding request in February.

Executive Session

Due to time constraints the Board opted not to hold an executive session at this meeting.

Ms. Tasker moved to adjourn the meeting. Mr. Wille seconded the motion. The motion passed 6 to 0.

Adjourn

The meeting adjourned at approximately at 7:30 p.m.

Approved:

Bill Jochems – Chairman
Healthy Rivers and Streams Board

Attest:

Lisa MacDonald

ASPEN VILLAGE METROPOLITAN DISTRICT

711 East Valley Road, Suite 103 (p) 970.273.3100 (f)970.797.1851

Donnie Lee, President Richard Jackson, Vice-President David Ritter, Treasurer
Mike Haman, Secretary Brent Ford, Director Gary Beach, Manager

Healthy Rivers & Streams Board

RE: Grant Funding 2012

District Structure and operation:

The Aspen Village Metropolitan District, located at 31300 State Highway 82, comprising 44 acres including 159 residential lots, of which 149 are currently developed. The District serves a population of approximately 400 persons, with water and sanitary sewer service. Although the District was formed in November 2003, Aspen Village has been in operation since the late 1950's. During the past 50 years, the infrastructure of the Village has undergone numerous small improvements but the corpus of the District's facilities exceed more than fifty years in service. The District's wastewater treatment plant consists of a three lagoon system, which has been in service for more than forty years.

Engineering Work to Date:

A Preliminary Engineering Report was produced and presented to the Board of Directors in June of 2009. This report is attached. This report lays bare the necessity for the replacement of the aging wastewater infrastructure and available options. These options, as stated in the report include modification of the existing facility to reduce nutrient loading, replacement with a package plant, and construction of an engineered plant. These options range from $35,465 for the proposed pumpback effluent system and $475,000 for a "package plant".

The system operates under a discharge permit issued by the State of Colorado, No. COG-58800 and facility No. COG-588085. This permit (exhibit 4) allows up to 99,000 gallons per day of treated effluent to be discharged into the waters of the Roaring Fork River. The existing wastewater treatment plant for the Aspen Village Metro District remains in compliance, although it is pushing up against the limits for discharge of Ammonia Nitrogen in the effluent. The present lagoon system removes approximately 88% of the ammonia nitrogen and 94% of the BOD.

Considerations:

Costs are a consideration due to the nature, structure and valuation of the District. Aspen Village is a deed-restricted development, currently redeveloping from a traditional mobile home park into a community of modular and 'stick-built' structures. The assessed valuation in 2008 of the 159 lots was $2,667,000 ($16,776 average) which will generate approximately $297,366 in 2013 with a mill levy of approximately 84 mills. Already one of the highest in Pitkin County. This creates challenges in securing funding from traditional sources in the form of grants, such as the Revolving Loan Fund, as these require valuations above and beyond those in Aspen Village.

Taking these constraints into consideration along with the natural beauty and environmental ethos of the larger community in the Roaring Fork watershed, the District is proposing a number of solutions, which would meet the Healthy Rivers objectives of maintaining and improving the water quality and quantity within the Roaring Fork watershed.

Here are the funding requirements and proposed structure of three distinct options with benefits to the water shed explored for each:

OPTION #1 – PUMP BACK RECIRCULATION MODIFICATION

Funding Application: $25,000
The Distict is seeking funding to cover the substantial cost of this modification.

Feasibility, Design & Planning: Done at a cost of $9,000
Evaluate project costs to cover the following elements: specification of needed materials, man power & permitting.

Project cost: $35,465:
>Material costs (pump, pipe & manhole): $31,865
>Labor & electrician to install: $1,600

Municipal & Environmental Permit Applications: $2,000*
*to be borne by the District (estimated cost)
>Research and satisfy all government & municipality permits necessary

Potential benefits vs replacement with similar waste treatment facililty as currently exists:
>33% reduction in both BOD & Ammonium Nitrogen discharge into the Roaring Fork River

OPTION #2 – PACKAGE / MODULAR PLANT

Funding Application: $205,000
>Feasibility study to investigate construction of a package plant to process wastewater materials on site while maintain current treatment during transition.

Feasibility, Design & Planning: $5,000
>Seek cost for feasibility analysis/construction costs by a qualified engineer

Project cost: $475,000:
>Design, construct and field engineer plant by a qualified engineer

Municipal & Environmental Permit Applications: $2,000*
*to be borne by the District (estimated cost)
>A package plant offers a well known technology which lowers the costs of permitting

Potential benefits vs replacement with similar waste treatment facility as currently exists:
>Meet the discharge limits and other requirements of their Discharge permit
>Reduction of BOD & Ammonium Nitrogen discharge into the Roaring Fork River

OPTION #3 – CONSTRUCTION OF A BATCH PLANT

Funding Application: $250,000
>Feasibility study to investigate construction of an ECOH2O and CHEMSTOR technology.
>Design of treatment plant, including site layout, building, inflow, outflow, architecture, landscaping, and any other required elements.

Feasibility, Design & Planning: Included

Project cost:
>The cost of installation of this facility will be borne by the engineering company under a licensing agreement whereby the cost of treating water at a rate of $8.33/1000 gallons will be assessed to the District. The proposal allows for any funds the District receives to directly reduce the capital cost associated with treatment assessed the homeowners of the District. The funds requested would provide the homeowners of the District, already assessed one of the highest mill levy's in the valley, comparable cost of treating water as those of other municipal providers in the region. A detailed cost analysis will detail the grant dollars and the direct impact to the homeowners in providing at a reasonable cost.

Municipal & Environmental Permit Applications: $2,000*
*to be borne by the District (estimated cost)
>Research and satisfy all government & municipality permits necessary

Potential benefits vs replacement with similar waste treatment facililty as currently exists:
>Reduction to zero release of BOD & Ammonium Nitrogen discharge into the Roaring Fork River with potential reuse
>Meet the discharge limits and other requirements of their Discharge permit without reuse

By______________________________
Gary Beach
District Manager

Aspen Village Metropolitan District
Wastewater Treatment Facility Planned Upgrade
Preliminary Engineering Report

FINAL DRAFT

I. Executive Summary

Aspen Village Metropolitan District is a Colorado Special District, formed in November 2003 for the purpose of providing public infrastructure and municipal services to the residents of Aspen Village, a rural subdivision. Aspen Village is a deed restricted community[1] that is redeveloping from a traditional mobile home park to a community of modular and 'stick-built' permanent structures. It is comprised of approximately 44 acres and includes 159 residential lots, of which 149 are currently developed. The District serves a population of approximately 450 persons, with water and sanitary sewer service provided to mobile homes, trailers, modular homes, pre-fabricated homes and 'stick-built' structures and a single commercial property. The subdivision is located at 31300 State Highway 82 in an unincorporated area of Pitkin County, Colorado.

Although the District was organized in November of 2003, it has been in operation since the late 1950s. During the past 50 years, the infrastructure of the Village has undergone numerous small improvements but the corpus of the District's facilities have been in service for more than fifty years, including the District's wastewater treatment system which consists of an aerated three lagoon process. These lagoons currently take several weeks to fully process the waste water delivered to it. As an alternative, today's new wastewater treatment plants can process the same volume of wastewater in less than one day.

Because the current discharge permit for the District's lagoon system will expire on May 31, 2013, the District has taken a proactive approach to determining if the existing system will need to be improved, repaired, rehabililtated or replaced before its physical and economic life has been exceeded, and in order to determine if it will still meet permitting requirements in 2013. As part of that determination, the District retained the planning and engineering services of Beach Resource Management, to evaluate the ability of the existing lagoon system to provide full compliance through and beyond 2013. This is partly due to the limited ability of the District to raise significant funds for the full replacement of its wastewater collection and treatment system, especially in light of the downturn in the national and local economy.

Several alternatives were evaluated ranging from minor modifications and improvements to the existing system, to a full replacement treatment plant. Because costs were and

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1 The 2010 assessed value of the 159 lots is $4,149,640 ($26,098 average), which will generate approximately $297,475 in 2010 with a mill levy of 71.662 mills. This mill levy is already one of the highest in Pitkin County.

continue to be a vital consideration, the alternative selected involves costs estimated to be less than $30,000 and includes the design and installation of a recirculating effluent system. Quite simply, this system requires minimal disruption to the existing plant, minimal new infrastructure and minimal capital and life-cycle costs.

The recirculating effluent system captures a portion of the fully treated flow at the outlet of the finishing pond and using a pump-back pipe system, delivers this flow back to the first lagoon in sequence. The simplicity of this system makes it a very workable solution as it takes fully treated effluent and pumps it back to the inlet of the first lagoon in the system. The re-introduced effluent/influent water is mixed at the point of entry to the first lagoon and consequently the chemical/biological concentrations are immediately reduced below the levels found in the new influent only. Thereafter, the required residence time in the lagoon system can be reduced, resulting in a commensurate reduction in vegetative growth in the lagoons, an overall benefit to the lagoon system and the final receiving stream. Quite simply, this is a practical application of the adage, "the solution to pollution is dilution."

This proposed modification of the existing lagoon system will allow the District to continue to meet the compliance requirements of its discharge permit while also allowing the District additional time to plan for the ultimate replacement of the lagoon system with a more advanced and economic package plant, including the identification of possible sources of funding.

2.0. Planning Conditions

2.1 The planning area of this PER includes only the Aspen Village Metropolitan District's corporate boundary and all demands within it (see attached boundary map and vicinity map). There is no current plan to expand the corporate boundary of the District, nor its approved service area. However, should additional properties petition to include into the District's service area, it would be incumbent upon the District's Board and constituents to determine if adequate capacity exists to service the expanded area and if no capacity exists, the petition would either be denied or the petitioner would be required to upgrade facilities to provide the required additional capacity.

2.2 The Aspen Village Metro District wastewater treatment facility is 208 Plan compliant.

2.3 According to Pitkin County's demographic forecast, population growth

estimates for the county have been estimated to hold steady at 2.3% until 2010 then begin to drop below 2%, declining to 1.5% by 2030. Continued growth forecasts are said to be driven by second home purchases, which cannot occur in Aspen Village, and second home purchases have been substantially reduced in the past year. For purposes of this engineering report, growth at Aspen Village was considered to be stable and we have assumed a liberal 2% growth in population through the planning period of five years.

2.4 Consequently, the wastewater flow forecast and the waste load forecast for the same period remains tied to the population growth at 2% and does not result in the need for additional wastewater treatment capacity during the current planning period.

2.5 Waste load forecast. See section 2.4

3.0. Description of Existing Facilities

3.1 Aspen Village is provided domestic and municipal water service by groundwater wells drilled into the Roaring Fork River alluvium. The District also receives irrigation water from the Brush Creek Ditch, which limits the amount of water diverted for irrigation of recreational areas, a ballfield, and some common area irrigation.

All wastewater is collected by the District's aging collection system which includes pipe materials ranging from transite, to clay, to plastic. There is indication of minor inflow and infiltration problems in the collection system and the system's class "A"operator is responsible for ensuring that effluent discharged meets all state standards and requirements. Wastewater is delivered to the District's treatment facilities by both gravity and a single lift station serving one commercial property.[2] Recent renewal of the Discharge Permit found "No adverse affects from the treated wastewater discharged are anticipated."

3.2 the Aspen Village lagoon system consists of two primary aerated lagoons and a third polishing lagoon (see Exhibit 3 for layout of lagoon system)

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2 There is only one lift station in the District's service area and it is utilized to pump sewage emanating from the rest rooms and a sink at a convenience store to the lagoon system. This lift station has two 100-gpm pumps located 3.5 feet off the floor of the wet well. Average daily flows from the store are 500-1000 gallons.

and a chlorine contact chamber. Lagoons 1 and 2 are aerated and have an estimated combined capacity of 800,000 gallons. Lagoon 3 has an estimated capacity of 750,000 gallons. Average influent flows were measured at 24 gpm and 30 day average daily flows are calculated to be 34,100 gallons, or approximately 92 gallons per day per residential bedroom, well within the range of reasonable municipal use.

3.3 The system operates under a discharge permit issued by the State of Colorado, No. COG-588000 and Facility No. COG-588085. According the system operator, this permit (see Exhibit F) allows up to 51,000 gallons per day of treated effluent to be discharged into the waters of the Roaring Fork River.

3.4 As stated previously, the AVMD lagoon system receives a thirty day average daily flow of approximately 34,100 gallons per day with a peak flow estimated to be (51,000 gpd).

3.5 The median household income for Aspen Village homeowners is less than the state average of $47,203, while the cost of living in the Aspen area is substantially higher than the state average. Utility users within Aspen Village had the highest mill levy of any taxing district in Pitkin County at 99.662 mills until properties were revalued and the mill levy dropped in 2009. The current mill levy of 71.662 mills is required for operations only and does not currently service any debt. Because of the current economic condition within the County and the State, the probability of selling bonds to fund a new wastewater treatment facility is very low.

Therefore, cost was a logical consideration when evaluating alternatives that would aid the District in present and future compliance with state water quality regulations and the federal Clean Water Act. The range of costs to maintain compliance through the permit period and beyond fell between $27,639.00 for the proposed effluent pump back system, and $475,000 for an installed "package plant." For reasons of fiscal conservancy, the engineer recommends that until such time as the District can support the cost of a new treatment plant, the pump back plan be pursued by the District and approved by the State Water Quality Control Division.[3]

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3 The estimated cost for a constructed-in-place multiple stage treatment plant fell within the range of $1,020,000 and $1,278,000.

4.0. Project Need and Purpose

4.1 The existing wastewater treatment plant for the Aspen Village Metro District remains in compliance, although it is pushing up against the limits for discharge of Ammonia Nitrogen in the effluent. Data provided by the system operator indicates that in the present configuration of the system approximately 88% of the ammonia nitrogen and 94% of the BOD is removed by the lagoon system. The average annual influent flow rate is slightly more than 20 gallons per minute, so if the proposed recirculated flow system is designed for 20 gpm, the mixing ratio at the inlet to pond no. 1 will be 50% influent and 50% treated return flow. For this mixing ratio, the Biochemical Oxygen Demand of the discharge to the Roaring Fork River will be reduced from 6.4% to 3.3%, and the Ammonia Nitrogen concentration will be reduced from 12.5% to 6.7%, a reduction of nearly 50% in each case, resulting in a higher level of effluent discharge quality than achieved today.

While the proposed change to the existing system is relatively simple, the mathematics of the analysis is somewhat more complex. This is due to the fact that portions of the "return flow" treated effluent will have been through the system up to a theoretically infinite number of times. This results in an infinite series form:

$$y = a(1 + x + x^2 + x^3 + \ldots + \ldots)$$

which can be truncated to $y = a(1 + x + bx^2)$ without loss of accuracy. In this formula, y represents the fraction of the wastewater constituent (BOD or Nitrogen) that would be discharged to the Roaring Fork River, given the following design parameters:

1. Influent, effluent and return flow for a given month, and
2. Percent constituent removal $(C_i - C_f)/C_i$ in the system in its present configuration.

4.2 Security for the AVMD system has never been a problem, but ever changing demands for space, encroachments of the plant site continue to concern the operator and the District. The District will also be proposing to install new security fencing around the sewage lagoons, the pump back system and the influent pipe and effluent discharge point. The District does not presently have this security fence within the 2010 budget but is considering it as part of the overall pump back project.

4.3 The operation and maintenance of the current system is not anticipated to change. There is no proposed change in operators nor any change in the method of operation for the WWTP. The proposed pump back project will change the overall operations and maintenance very little with the exception of maintenance to the new pump system and buried pipeline.

4.4 The Aspen Village Metro District is considered fully built out even though an additional ten lots could be sold. At the present time, the Aspen Village Homeowners Association owns those lots and does not anticipate selling them as they provide a buffer between existing homes and recreational fields. Therefore, only nominal growth is projected (2%) in order to accommodate the conversion of mobile homes and trailers to more permanent forms of domicile.

5.0 Assessment of Alternatives

5.1 Several alternatives were evaluated as a part of this Preliminary Engineering Report. These included a "No Action" alternative, which evaluated the conditions today, the projected growth of the District and the need to take action or not. It was determined that the "No Action" alternative would not serve the best interests of the District although it was the least cost alternative.

The PER also evaluated a package plant approach aimed at providing full compliance with all water quality standards and those requirements of the current discharge permit. Several treatment options were evaluated including an improved aerated pond system,[4] an aerated pond system with other treatment processes, a batch reactor plant, and an engineered advanced treatment plant. While the cost of constructing a package plant falls within the range of reasonableness ($382,000 - $475,000), the District simply cannot afford even the most reasonable cost of a package plant at this time. The package plant also brings with it an issue that will need to be resolved whenever a traditional plant is designed to replace the existing lagoon system, that is the issue of how to continue operation of the existing plant while building a new plant in the same location.

One option that we reviewed and which appeared to resolve both cost and siting considerations was the ECO H2O Wastewater Purifier and CHEMOSTOR Bio-solids Converter. The ECO-H2O water purifier is

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4 This would include physical modifications to the existing ponds to optimize treatment.

based on an inonic and molecular sieve separation of impurities, and when coupled with the bio-solids converter treats wastewater to discharge standards with a very small plant footprint. For example, a plant sized to treat AVMD's wastewater is estimated to require about 3,000 square feet of area. The combined capital and operational cost of the plant is estimated to be $6.48 per 1,000 gallons, which is substantially less costly than a design build plant. Unfortunately, this technology is not yet approved by the State of Colorado.

The PER also evaluated an engineered WWTP, with construction of a built-in-place multiple treatment stage plant to provide tertiary treatment of wastewater flows. This approach, although considered to be technically superior, was also considered to be unaffordable for a 51,000 gallon per day plant. All inclusive cost estimates for this plant were approximately $1,278,000.

5.2 The criteria used to evaluate the various alternatives was influent volume using both average and peak flow rates, influent constituency, historic changes in constituency, inflow, infiltration, discharge requirements, treatment options and both capital and life-cycle costs. The included costs for state and local design review and permitting.

5.3 At this stage of the analysis, environmental considerations were minimal, however, issues such as odor, aesthetics, impacts to wildlife and humans were all evaluated. The proposed pump-back option has no significant impact on existing conditions as the pump and pipeline will be constructed immediately adjacent to the existing lagoons within the plant's activity envelope.

5.4 Land requirements were briefly studied to determine the land size requirement by each option. This included the study of where to locate the new facility while the existing facility remained in operation. The existing lagoon system covers an approximate area of 2.0 acres. Modifications to the site will be needed to complete any alternative other than the pump back project, which would be wholly contained within the existing site footprint.

5.5 Construction will be significantly simplified due to good access from State Highway 82 and direct access to the site off Aspen Village Road. Truck traffic will not need to go through the subdivision to get to the WWTP site and construction staging will be possible due to an available storage lot on

site.

5.6 It is proposed that the existing lagoon system will remain in operation during the construction project. This reduces the viability of other options while increasing the cost effectiveness of the pump back option.

5.7 Cost estimates have been generated using local historical 2010 construction and commodity rates. The cost estimates range from $27,639 for the pump back option to the next most cost effective option, which is approximately $475,000 with design, construction and field engineering and construction management for an appropriately sized package plant. Today's least affordable approach for Aspen Village is an engineered, built-in-place plant for an estimated $1,278,000.

Because the ECO-H2O plant is financed by the manufacturer, this cost was not used for comparison as the cost provided to the District includes both capital and operational costs. Although this is an attractive option to the District, it cannot be pursued today due to the need for approval of this technology by the State.

5.8 Because funding sources are limited and grant monies do not appear to be easily available, Aspen Village Metro District's options are substantially limited. Due to its existing high mill levy for operations, the pump back option is currently the only option being recommended to the District's Board of Directors and Constituency.

EXHIBIT “A”
VICINITY MAP - ASPEN VILLAGE

EXHIBIT “B”
AERIAL PHOTOGRAPH & TOPOGRAPHIC MAPPING

EXHIBIT "C"
PHOTOGRAPHS - ASPEN VILLAGE LAGOONS

EXHIBIT "D"
HANSEN TECHNICAL MEMORANDUM

EXHIBIT E
ECO-H20 WWT PLANT PROPOSAL

EXHIBIT F
EXISTING PERMIT

EXHIBIT G
PROPOSED PROJECT COST ESTIMATE

PITKIN COUNTY

PUBLIC WORKS

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February 4, 2013

Pitkin County Healthy Rivers and Streams Board
530 E. Main Street Ste 302
Aspen, CO 81611

Subject: Aspen Airport Business Center Stormwater Treatment Grant Application

Dear Healthy Rivers and Streams Board,

Pitkin County Public Works has been undergoing an engineering and planning project for the roadways in the Aspen Airport Business Center (AABC) since 2008. This project consists of rebuilding the roads, adding pedestrian amenities, and most significantly, correcting and adding drainage features. The project has been included in the 2013 Capital Plan and will be under advertisement for proposals in February of 2013.

The current drainage situation in the AABC is a hodgepodge of rural style ditches, patch works of drywells, intermittent curbs, and a system of undersized pipes. The current system regularly fails and creates debris flows, floods buildings, and does not treat any of the water before it makes its way to the Roaring Fork River.

The AABC Road Reconstruction Project proposes to collect much of this water across the AABC with a curb and gutter system along the 100, 200, 300, and 400 roads. This water will be collected into a storm sewer system along Baltic Ave (AABC 500 Rd) and transported down a pipe to a settling pond located on a bench adjacent to the Stein trail. This pond will be able to collect water and dissipate the energy and collect the particulates out of the water.

This grant application is for the stormwater quality features on the project. Items include excavation to create the pond, appropriate outlet structures from the pond, and the piping of the water from the treatment area to the Roaring Fork River.

The remainder of this document will touch on the 7 goals outlined in the protocol and guidelines of the river board listed on the website.

Viability of the Project
The project was included in the County's 10 year Capital Plan for the 2013 budgeting project with a $2.6M projected budget. This budget was originally set without including the water quality aspects discussed. It is anticipated that an additional $150,000 will be needed to complete the water quality pond and its appurtenances. The project will be advertised for bid proposals through the month of February.

Public Accessibility
This project will result in the addition of a storm-water system which a large part of will be located along the Stein Trail. This trail is located between the AABC and the Roaring Fork River. During many storm events this trail will wash out. The project as proposed, while focused on treating water received from the AABC, will ultimately serve to protect the trail from washing out, further reducing the amount of sediment into the Roaring Fork River and protecting a key connection between the AABC and North 40 communities and the Roaring Fork River and Rio Grande trail.

Goals of River Board
The River Boards goals as stated in the bylaws include language regarding water quality; ensure ecological health, wildlife and riparian habitat and most specifically about improving and constructing capital facilities that contribute to these objectives. The proposed water quality aspects of this project fall directly in line with these goals.

Prospect of Repetition of Project
Since this project is seen as a one-time capital expenditure at this time to construct the facilities, the project in of itself is not seen as repeatable.

History of the Requesting Party
Pitkin County has a long history of environmental stewardship including the creation of the Healthy Rivers and Streams and the Open Space and Trails program. Controlling and treating the storm runoff from one of the few urbanized areas within the County's road system is a logical and responsible aspect to that stewardship.

Participation by Other Parties
The bulk of the AABC Roadway Project will be funded by Pitkin County's General Fund. The total drainage improvements proposed are estimated to be at least $750,000. This grant application is for $150,000 of those improvements.

Proposed Project Budget
The general fund budget for the entire AABC Roadway Project is $2.6M. Pitkin County Engineering Staff can produce real project costs once proposals are received from the contractors.

Thank you,

G.R. Fielding, PE
Pitkin County Engineer

Drought-Year Baseflow Monitoring on Select Reaches in the Roaring Fork Watershed.

February 13, 2013

Prepared For:

PUBLIC COUNSEL
of the rockies

and

ROARING FORK
CONSERVANCY

In Accordance With:

ROARING FORK WATERSHED PLAN

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Summary

During the fall of 2012, Friends of Rivers and Renewables (FORR), an initiative of Public Counsel of the Rockies, and the Roaring Fork Conservancy (RFC) initiated an effort to periodically collect streamflow data on eight stream reaches previously identified as candidates for permanent streamflow gauge installation. This work aimed to characterize baseflow hydrological conditions on the selected study reaches and assess the adequacy of existing streamflow gauging infrastructure or watershed modeling techniques to inform stakeholder groups on those conditions. Importantly, the data and discussions presented in this brief should be considered within the context of the ongoing efforts of FORR, RFC and others to enhance the availability and effectiveness of hydrological data collected across the Roaring Fork Watershed.

Reach selection for this work followed from the findings of the *Stream Gauge Needs Assessment Workshop,* hosted by FORR and RFC in April 2012, and a subsequent report, *Site Recommendations for Stream Discharge Gaging on Top Tier Priority Reaches in the Roaring Fork Watershed,* (S.K.Mason Environmental, LLC, 2012) that further refined potential gauging locations. The *Stream Gauge Needs Assessment Workshop* identified the need for better information on streamflow to aid resource management decisions regarding water quantity and quality on select stream reaches across the watershed. These reaches were termed *top tier reaches*. The availability of stream discharge data from state and federal agencies or the need of further stakeholder engagement before proceeding with plans to install new gauging infrastructure led to the removal of several reaches from the top tier list. Reaches removed from the list include the upper Fryingpan tributaries due to ongoing gauging at tunnel inlets by the Bureau of Reclamation; the upper Roaring Fork at Lost Man due to difficult seasonal access issues and existing water exchange agreements; and the Roaring Fork at Smith Way Bridge, which is too large at most flows to safely obtain discharge measurements via the wading method. The sites monitored during this effort correspond to the following top tier reaches:

1) Roaring Fork River near Aspen ("suite of gauges")
2) Maroon Creek at the CoA Municipal Diversion
3) Maroon Creek below Stapleton Brothers Ditch
4) Coal Creek
5) Brush Creek
6) Lower Crystal River

The following brief provides summary discussions of each data collection location, how the information collected at these locations contributes to current initiatives of FORR and RFC, and how this data may inform discussions on prominent water resource issues in the Roaring Fork Watershed. Streamflow monitoring and subsequent analysis aimed to meet the following goals:

- Provide baseflow streamflow data, characterizing conditions on each of the study reaches during the drought conditions of 2012
- Determine whether or not valuable water resource management information is gained by collecting streamflow data on each of the study reaches

- Assess whether or not the top tier sites as identified by the *Stream Gauge Needs Assessment Workshop* and subsequent reports are appropriately located.

Methods

Discharge was measured manually using the velocity-area method described in *USGS Techniques and Methods 3-A8* (Turnipseed and Sauer, 2010) with a handheld Sontek Flowtracker® Acoustic Doppler Velocimeter. To compute discharge, a suitable stream cross section was first identified by a combination of a desired location on the study reach, adequate channel shape, and available river access through public right-of-ways or landowner permission. Measuring discharge using the velocity-area method is based on several assumptions, including uniform flow in a downstream direction at an ideally shaped cross section. Several measurement locations on the steep and rocky reaches prevalent in the Roaring Fork and Crystal watersheds were only rated 'fair' to 'good' measurement locations due to excessive turbulence, which increases the potential for measurement error. Even though channel geometry and hydraulics at several locations pushed the boundaries of the methodological assumptions, the employment of thorough quality assurance and quality control procedures ensured that discharge measurements provided accurate estimates of flow. Streamflow data collection on each of the seven reaches began in late August and continued on a bi-monthly schedule until the end of October.

A variety of sources provided additional information required for data analysis and interpretation. The *Stream Gauge Needs Assessment Workshop* provided background information on each of the top tier reaches (available at www.roaringfork.org/publications). The City of Aspen's Response to FERC Schedule A Information Request Letter dated March 27, 2012 provided additional information regarding annual flow data for Maroon Creek. The City of Aspen generated this letter to answer stakeholder questions concerning the proposed Castle Creek Energy Center and it includes historical streamflow and annual yield modeling for Maroon and Castle Creeks. Existing United State Geological Survey (USGS) and Colorado Division of Water Resources (CDWR) streamflow gauges provided streamflow data on several of the study reaches.

Selection of the appropriate analysis approach for each study location required consideration of the principle motivations for streamflow gauging on each of the top tier reaches as determined by the Stream Gauge Needs Assessment Workshop. The result: analysis approaches ranging from simple hydrological modeling to the direct comparison of manually collected data to data generated by existing streamflow gauges. A summary of the analysis approach used for each site is provided in the following sections.

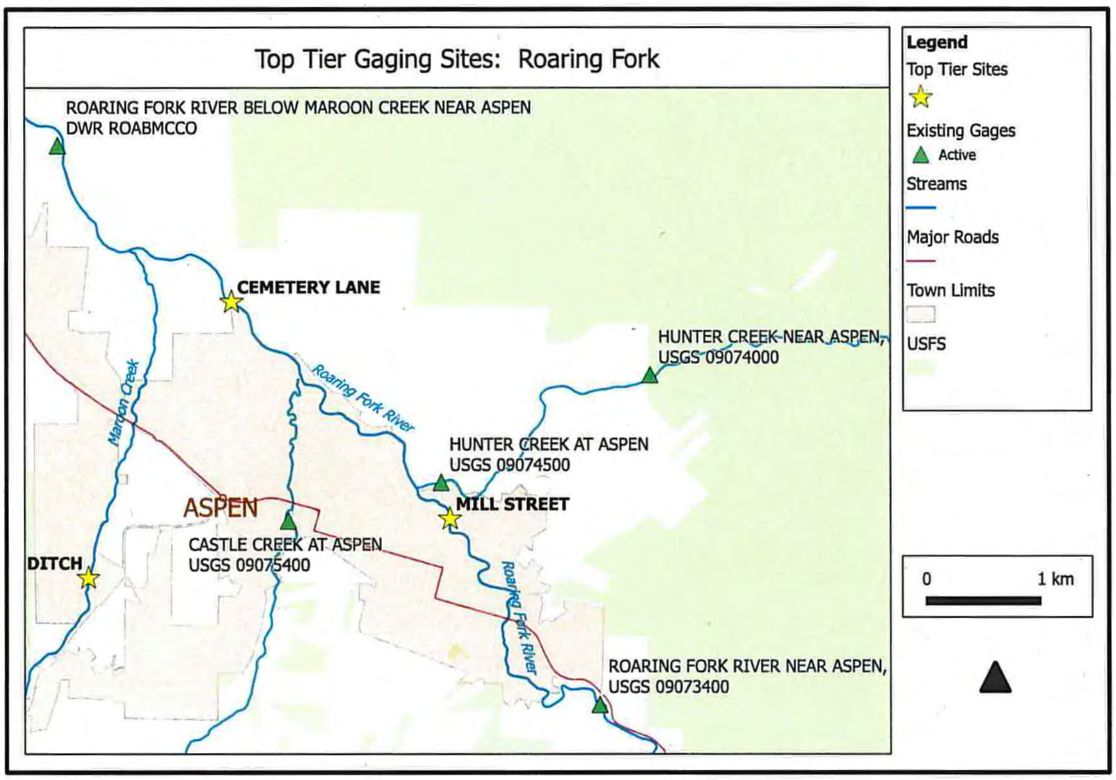
Roaring Fork River at Mill Street

Location

The Mill Street Bridge is located within the City of Aspen city limits near the existing Aspen Art Museum building. Streamflow monitoring occurred directly beneath the bridge at the following coordinates: N $39^{0}11'38.7"$ W $106^{0}49'02.2"$. The upper Roaring Fork River near the City of Aspen faces vulnerability to low flows resulting from trans-basin and local diversions. The USGS and CDWR operate

several gauges on this reach; however, these gauges do not collect data on the stream segments experiencing the greatest flow depletion—information which may be useful for administration of the year round Colorado Water Conservation Board (CWCB) Instream Flow (ISF) right on the reach.

Figure 1: Location map for upper Roaring Fork data collection sites.



Analysis Approach

The USGS gauge *09073400* is located just upstream of significant local water diversions at the Salvation, Nellie Bird, and Wheeler ditches. Flows measured at the gauge thus overestimate the volume of water flowing through the City of Aspen at any given point in time. The next downstream gauge, *CDWR ROABMCCO*, is sited near the Airport Business Park below the confluence of both Castle and Maroon Creeks. Flow measurements at this site are dominated by these large tributary inputs giving a deceptively robust picture of Roaring Fork River streamflow in the upstream reach. Direct comparison of observed streamflow data collected at Mill Street with the data collected by USGS gauge *09073400* allowed for quantification of the actual discrepancies between the two locations (Table 1, Figure 2).

Analysis Approach

Although continuous streamflow measurement on Maroon Creek by the USGS ceased in 1994, the City of Aspen periodically measures streamflow below the City's diversion point during the summer months. Unfortunately these records are neither long-term, nor made available by the City for use in this study. The absence of a continuous record of streamflow on Maroon Creek makes it difficult to predict impacts of proposed water use development plans. Understanding this issue and in conjunction with planning activities for the proposed Castle Creek Energy Center (CCEC), the City of Aspen conducted an analysis to model (read: estimate) monthly streamflow conditions for representative 'average', 'wet', and 'dry' years. Collecting field measurements of streamflow in years corresponding to representative 'average', 'wet' and 'dry' conditions identified in the CCEC study provides resource managers with a tool for evaluating model performance and better understanding the value of continuous streamflow records at this location on Maroon Creek.

The analysis presented here compares manually measured flows to the City of Aspen's estimated flows for a representative 'dry' year. Modeled data provided by the City of Aspen forms the basis for the hydrographs presented in Figure 5 (Response to Information Request Letter, 2012). Modeled 'dry' year flows provide useful context for the 2012 observations, while the new data simultaneously serves to cross-validate model performance. While a rigorous statistical comparison of measured and modeled flows is both beyond the scope of this report and prohibited by the sparse data available here, a qualitative interpretation of results suggests a good model fit to the data for a representative 'dry' year. Conclusions regarding model accuracy may vary depending on whether 2012 is characterized as drought-year outlier, or representative of 'average' conditions in the face of climate shifts in the southern Rockies favoring drier weather patterns. More data collected across a range of streamflow conditions on upper Maroon Creek will both provide further information to calibrate and validate streamflow models for the watershed, and will help resource managers understand the way that changing climate conditions affect trends in watershed yields, hydrograph timing, and resultant impacts on resource use plans and the ecological function of the stream.

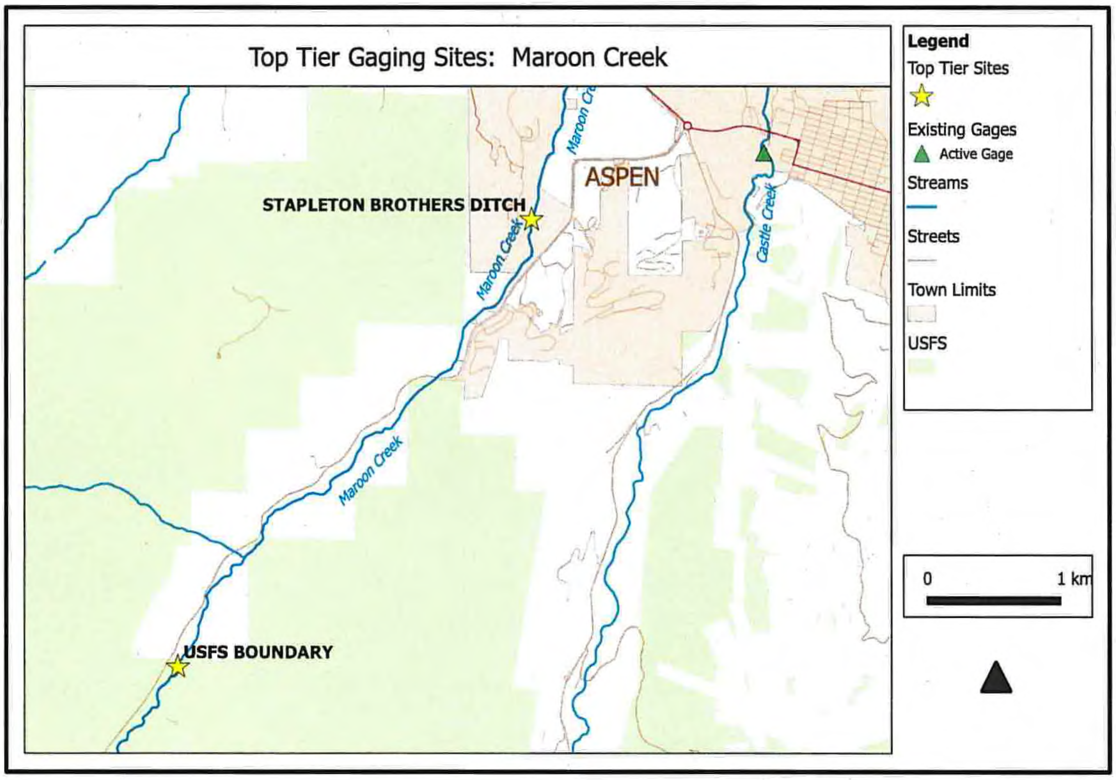
An ISF right of 14 cfs exists on both measured segments of Maroon Creek. Observations above the City of Aspen diversion and below the Stapleton Brothers Ditch exceeded that amount on all observation dates. However, the most flow-depleted segment, which exists between the City of Aspen diversion point and the return flow outfall from the Maroon Creek hydroelectric station, could not be measured due to private property access restrictions. If diversions at the City of Aspen diversion point exceeded 12 cfs on any of the observation dates, streamflow in this segment of Maroon Creek could have dropped below the 14 cfs ISF right.

Maroon Creek

Location

Flow monitoring on Maroon Creek occurred upstream of the USFS Boundary, approximately ¼ mile below the Maroon Bells pay station on Maroon Creek Road at the following coordinates: N 39°09'27.58" W 106°53'03.21". This drainage point catches the majority of yield from the upper watershed excepting the tributary inputs from Willow Creek. The top tier reach identified for this section of Maroon Creek begins below the City of Aspen diversion. However, due to private property access constraints, the collection of streamflow measurements above the City of Aspen diversion. Additional observations occurred on Maroon Creek below the Stapleton Brothers ditch at the following coordinates: N 39°11'10" W 106°41'15". This location corresponds to the top tier reach identified for Lower Maroon Creek and may be accessed from the foot trail below the Aspen Recreation Center.

Figure 4: Location Map for Maroon Creek sites.

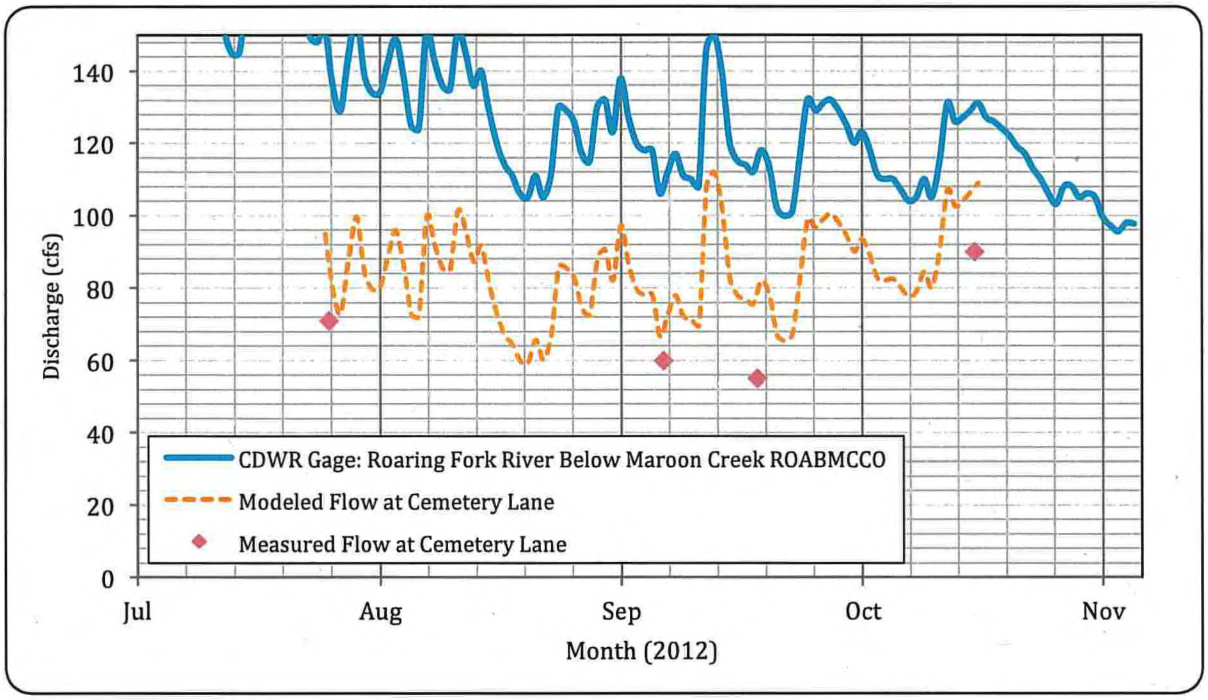


Streamflow inputs from Maroon Creek comprised a significant fraction of the total discharge in the upper Roaring Fork during the observation period. The upper observation location characterizes the natural stream flow absent significant diversions. A short distance downstream, the City of Aspen diverts water to Thompson Reservoir in the Castle Creek drainage. A hydropower plant on lower Maroon Creek also utilizes water from this intake, decreasing flows in several miles of Maroon Creek between the diversion point and the return flow outfall.

Table 2. Observed and modeled streamflow at Cemetery Lane.

Date	Measured Streamflow (cfs)	Modeled Streamflow (cfs)	Absolute Model Error (cfs)
7/25	71	95	+24
9/6	60	66	+6
9/18	55	76	+21
10/16	90	107	+27

Figure 3. Observed and modeled streamflow at Cemetery Lane. Real-time streamflow data recorded below the confluence with Maroon Creek at a CDWR gauge plotted for reference.



Site value to resource managers

Cemetery Lane is the approximate downstream City of Aspen city limit boundary. This site was identified by the *Stream Gauge Needs Assessment Workshop* as well-suited to characterize the water quality impacts of urbanization. A long-term water quality dataset exists for this site and ongoing water quality sampling is provided by River Watch volunteers at the Aspen High School. The site is also located on a segment of the Roaring Fork River that is provisionally listed on the 303(d) list for impaired waters. This listing carries the potential to affect any permitted dischargers on the segment. Paired flow data enhances the quality and power of water quality information collected at a site and will greatly assist in efforts to understand source loading of various water quality constituents to the river.

Roaring Fork River at Cemetery Lane

Location

Cemetery Lane leaves the City of Aspen's city limits on the northwest side of the city. Streamflow monitoring occurred beneath the footbridge located immediately upstream of Stein Park at the following coordinates: N 39°12'39.08" W 106°50'22.53". Cemetery Lane is a long-term water quality monitoring site used by the state and the citizen-monitoring organization River Watch. Paired flow data would enhance the quality and power of water quality information collected at this site.

Analysis Approach

Streamflow may be estimated at an ungauged site using existing gauges on a mainstem river and one or more tributaries. However, because no gauge exists on Maroon Creek and because the CDWR gauge located on the mainstem is located below the tributary input of Maroon Creek, use of this approach may be precluded on the Cemetery Lane site. The analysis presented here assesses the utility of a flow-estimation approach for determining conditions on the Roaring Fork River at Cemetery Lane.

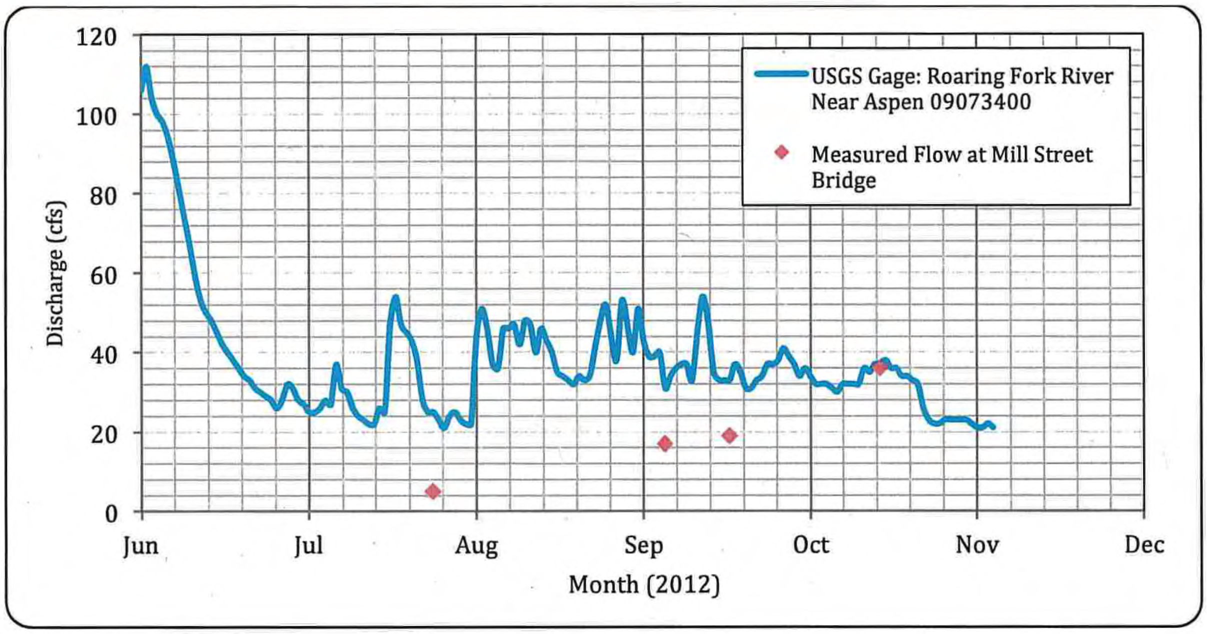
Construction of a simplistic hydrological model for estimating streamflow at Cemetery Lane required estimates of flow from Maroon Creek and the Roaring Fork River below the confluence with Maroon Creek. The CDWR's *ROABMCCO* gauge provided real-time streamflow data for the mainstem Roaring Fork River below the confluence with Maroon Creek. Manual collection of data from Maroon Creek occurred on four sampling dates. Linear interpolation estimated flows on Maroon Creek between sampling dates. A subtractive mass-balance model provided estimates of flow at Cemetery Lane. Subtraction of the modeled tributary streamflow data for Maroon Creek from the gauged flows on the Roaring Fork collected near the Airport Business Park at the CDWR *ROABMCCO* gauge yielded a set of estimated flows at Cemetery Lane. Notably, while this approach greatly oversimplified the system, it is deemed reasonable given the type and resolution of available data that could be used by resource managers for estimation of flow at the study site on an on-going basis.

Results show that inclusion of data from Maroon Creek in a subtractive model greatly improves estimates of flow on the Roaring Fork near Cemetery Lane; however, actual streamflows are still overestimated by the model (Table 2). The discrepancies observed between modeled and observed data may arise from the over-simplistic model construction (e.g. some tributary or groundwater inflows/outflows may remain un-accounted for) or may be exaggerated by the sparse nature of the observed data points. The source of the error will be difficult to determine without streamflow data from Maroon Creek of enhanced temporal resolution.

Table 1. Measured streamflow at Mill Street compared to data recorded at the upstream USGS gauge on the same dates.

Date	Streamflow @ USGS 09073400 (cfs)	Streamflow @ Mill St. (cfs)	Streamflow Difference (cfs)	Streamflow Difference (%)
7/25	25	5	-20	-80%
9/6	31	17	-14	-45%
9/18	33	19	-14	-42%
10/16	37	36	-1	-3%

Figure 2. This hydrograph displays the under-estimation of Roaring Fork flows at the Mill Street site during late summer and fall. The last data point records flows after large diversions immediately below the USGS gauge site have ceased for the season. The USGS gauge accurately estimated discharge on the lower river segment on the last data collection date.



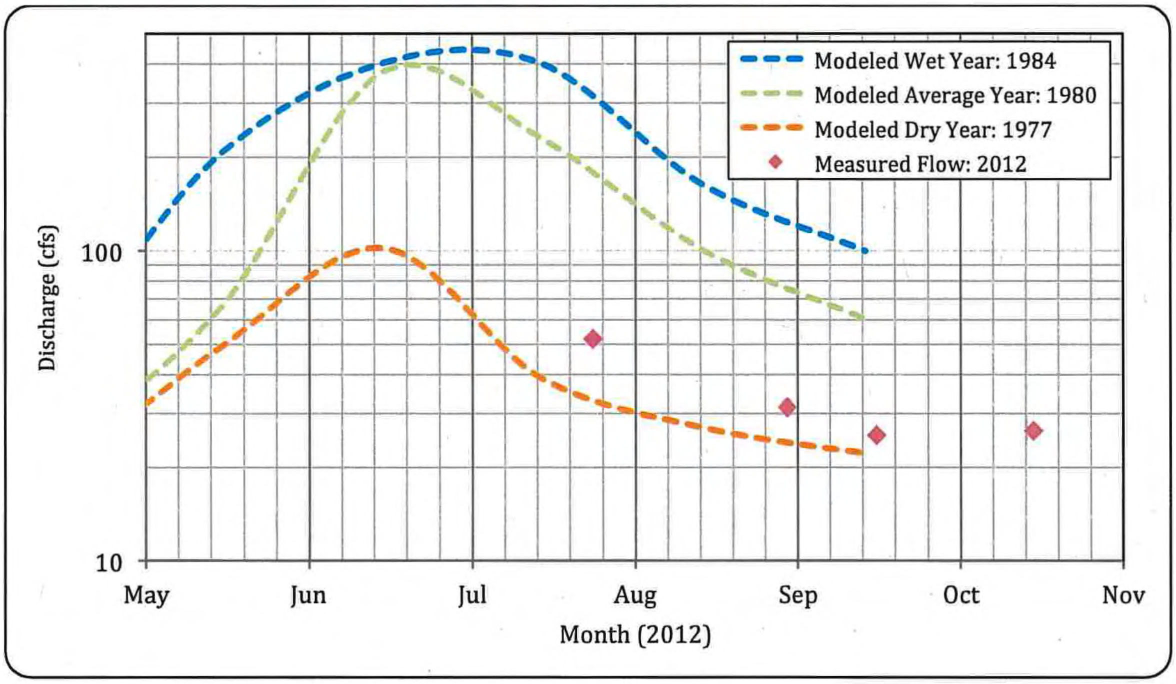
Site value to resource managers

Data collected from this site portrays river discharge downstream of impacts from local water diversions—information that cannot be determined from the data provided by the upstream USGS gauge. In this reach, the river faces significant vulnerability to low-flow conditions, with the attendant stress to aquatic communities and anticipated impacts to social and recreational values. A 32 cfs CWCB ISF right exists for this reach between the upstream confluence with Difficult Creek and the confluence with Maroon Creek. CWCB identifies 32 cfs as a minimum streamflow beneficial for the protection of environmental values on the Roaring Fork. The current absence of regular streamflow data collection at the Mill Street location may inhibit development of definitive conservation and management solutions aimed at improving stream health on this segment of the Roaring Fork River.

Table 3. Measured and modeled streamflow for Maroon Creek.

Date	Streamflow at USFS Boundary (cfs)	Streamflow Below Stapleton Brothers Ditch (cfs)	Modeled Monthly Mean Streamflow: Average Year (cfs)	Modeled Monthly Mean Streamflow: Dry Year (cfs)
7/25/2012	52	56	402	39
8/31/2012	31	41	100	27
9/17/2012	26	47	60	26
10/17/2012	26	22	-	-

Figure 5. Measured and modeled streamflow for Maroon Creek.



Data value to resource managers

In the face of climate change, it is unclear to what extent the modeled hydrographs produced by the City of Aspen for the CCEC study and the estimated annual water yield for Maroon Creek continue to accurately represent flow conditions Maroon Creek (Figure 5). Because the Maroon Creek watershed remains essentially undeveloped above the T-Lazy 7 Ranch, it serves as an important regional reference for water quality, natural flow regimes, and potential trends in watershed yield from climate change in the Southern Rockies. Continued discharge observations on Upper Maroon Creek may help inform management questions surrounding these issues on Maroon Creek.

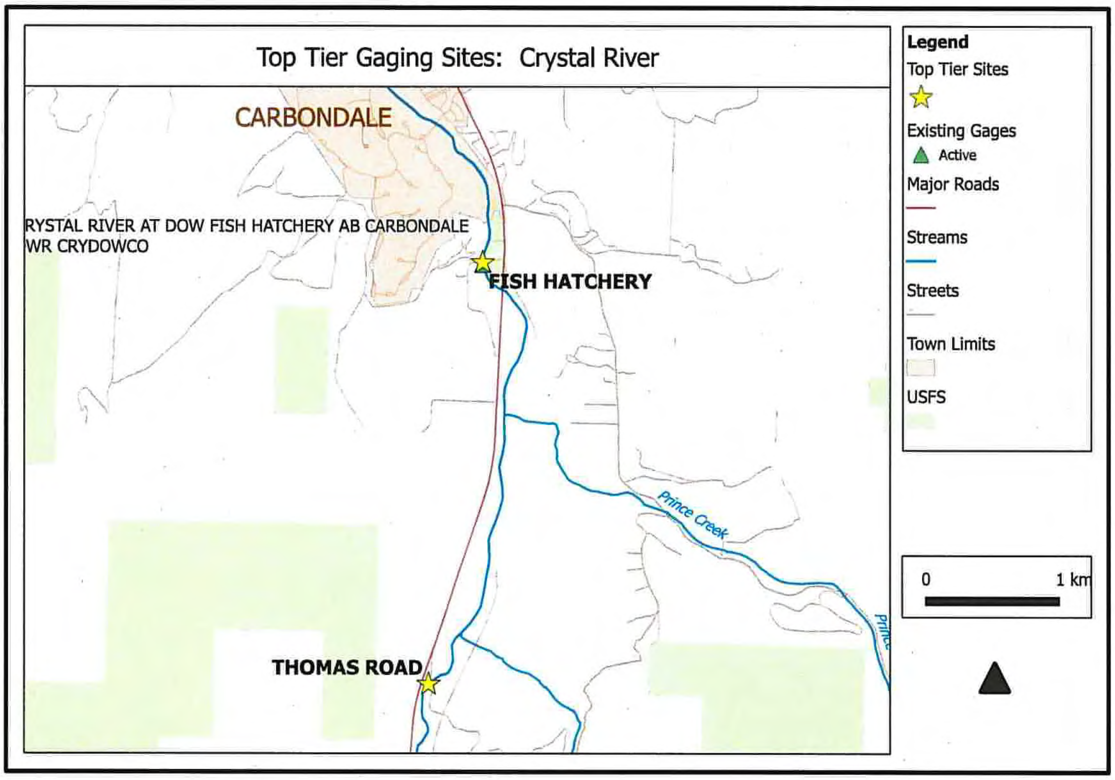
The Stapleton Brothers Ditch supplies water to sites near the Airport and is the center of a trust agreement initiated by Pitkin County to augment instream flows with County-held water rights. The inability to measure flows on this segment was cited by opposition parties in a challenge to Pitkin County's water right change request to the CWCB. Consistent streamflow monitoring below this diversion point would support administration of the CWCB ISF right on Lower Maroon Creek.

Lower Crystal River

Location

Flow monitoring on the Crystal River occurred at the CDPW Fish Hatchery in October after the CDWR streamflow gauge at this location ceased operation for the season. The CDWR gauge is located at the following coordinates: N 39°22'38" W 107°12'16". Collection of an additional set of manual streamflow measurements occurred at the Thomas Road Bridge located at N 39°20'56" W 107°12'31". Area water managers identified these reaches as prone to low streamflow during dry years. The Crystal River experiences significant variability in the timing and magnitude of streamflow on this reach due to the management activities associated with numerous upstream water diversions. CWCB holds a 100 cfs summer ISF right on this segment. Research conducted by RFC indicated that the ISF right was not met in two-thirds of all years since the 1950's.

Figure 6: Location map for Crystal River sites



Analysis Approach

The analysis conducted for this location aimed to identify whether or not the CDWR streamflow gauge at the CDPW Fish Hatchery adequately characterizes conditions on those segments of the Crystal most vulnerable to low summer flows.

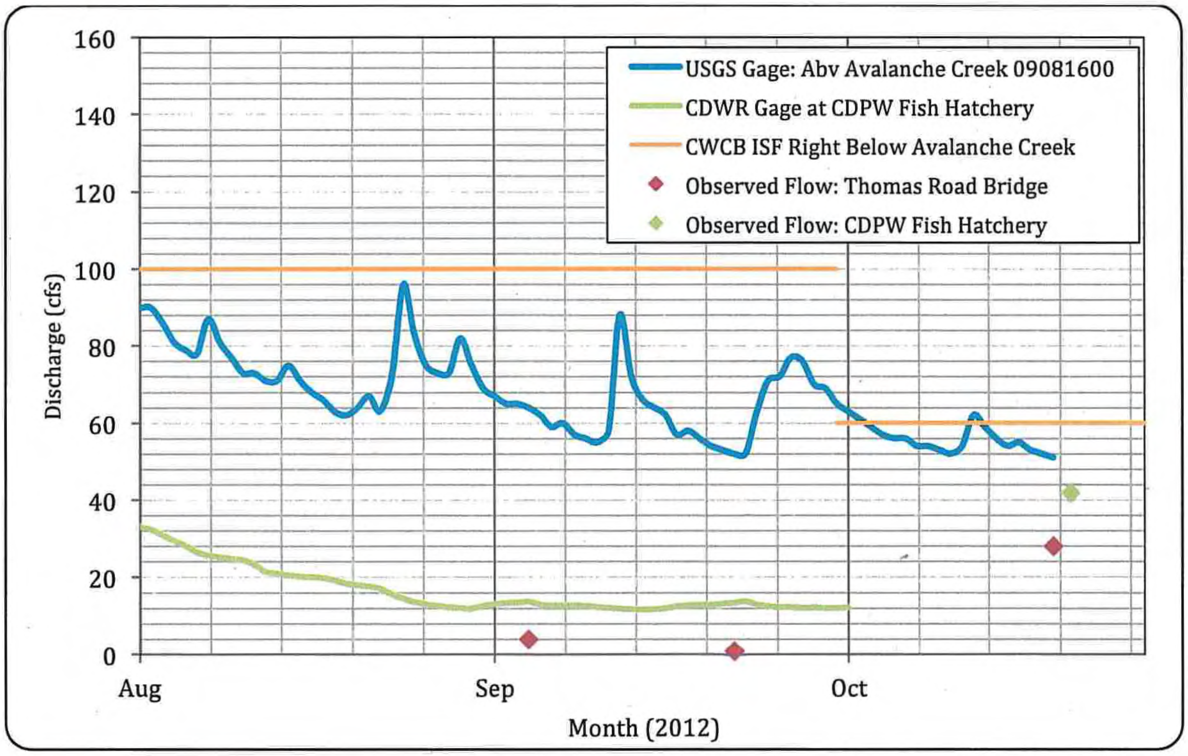
Data collected at Thomas Road site indicate that the CDPW fish hatchery site does not accurately characterize the magnitude of upstream flow depletion; however, it does appear to adequately characterize

general patterns in hydrograph timing. Thus, collection of streamflow data from the Thomas Road site may better illustrate the severity of flow depletions on the Lower Crystal River.

Table 4. Measured streamflows on the Lower Crystal River.

Date	USGS Above Avalanche Creek	CDWR Fish Hatchery	Thomas Road
9/4	64	11	4
9/22	52	9	1
10/20	47	-	28
10/21	46	42	-

Figure 7. Measured streamflow on the Crystal River at three locations: Avalanche Creek, Thomas Road Bridge and the CDWP Fish Hatchery.



Data Value to Resource Management

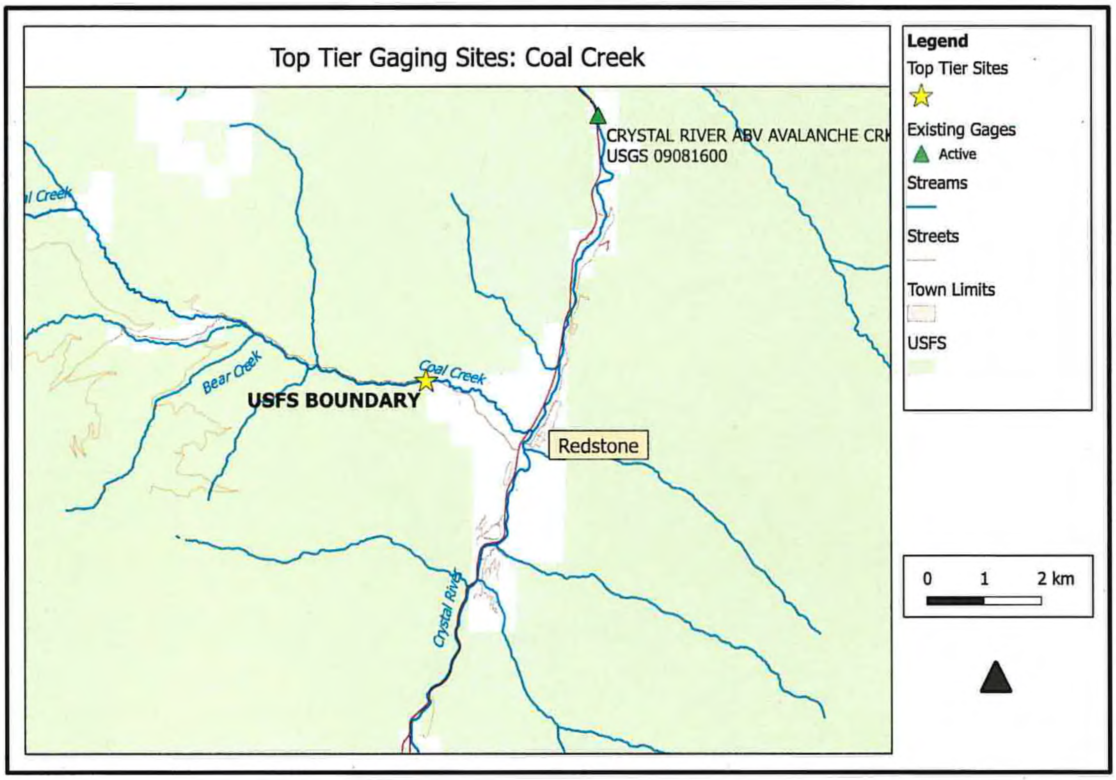
Instream flow issues continue to impact the ecological function and recreational value of the lower Crystal River. Ongoing efforts by multiple stakeholder groups attempt to address these issues. The current absence of regular streamflow data collection on the most severely flow-impacted segments of the Crystal River may inhibit development of definitive conservation and management solutions aimed at improving stream health on these segments.

Coal Creek at USFS Boundary

Location

Flow monitoring in Coal Basin occurred near the USFS Boundary at the following coordinates: N 39°11'24" W 107°15'43". This drainage point captures the majority of the basin's yield. Coal Basin was extensively mined for coal over the last century, and unstable mining roads and waste rock piles at high elevations in the upper basin are now viewed as a major contributor of sediment to Coal Creek. Channel aggradation of the Crystal River near the town of Redstone may be affected by sediment inputs from Coal Creek. Extensive restoration activities to address sedimentation issues in Coal Basin are either underway or in various stages of planning.

Figure 8: Location map for Coal Creek site.



Analysis Approach

Streamflow data is not consistently collected on Coal Creek. Alternative methods exist for estimating hydrological parameters at ungauged locations. These estimates provide context for understanding how the 2012 data more generally relates to estimates of average flow conditions in Coal Basin. The USGS web-application, StreamStats, utilizes regional regression equations to estimate flow parameters for ungauged streams (http://streamstats.usgs.gov/colorado.html). StreamStats compares characteristics such as elevation, aspect, slope, and precipitation in reference watersheds with existing stream gauges to

generate mathematical relationships for estimating flow parameters in similar, ungauged locations. StreamStats generated three statistics related to modeled low flow conditions at the drainage point corresponding with the measurement location used to collect the 2012 data. The generated statistics include the M7D10Y, Q9, and Q10. M7D10Y represented the 7 day average low flow corresponding to an event with a one in ten year return interval. The Q9 and Q10 statistics estimated the mean monthly flows for September and October. While 2012 flows were well below the estimated mean produced by StreamStats (which has a significant error range), they compared reasonably well to the 10 year low flow estimate of 1.26 cfs.

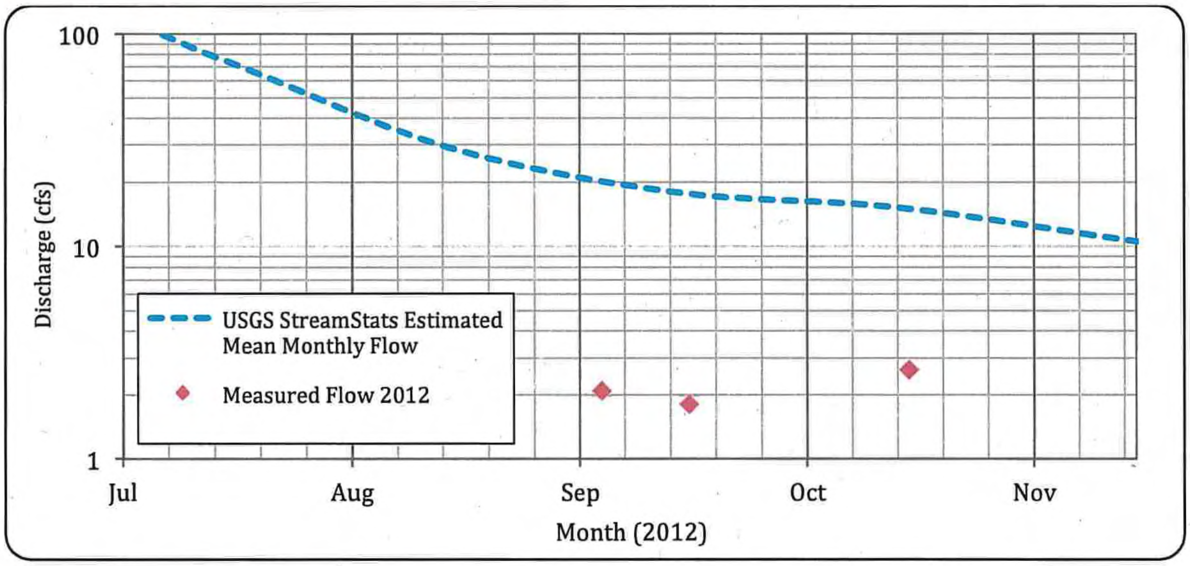
Table 5. Measured flows on Coal Creek and modeled predictions from USGS StreamStats.

Date	Observed Streamflow (cfs)
9/5/2012	2.1
9/17/2012	1.8
10/17/2012	2.6

StreamStats Model**	10 Year 7 day Low Flow	September mean	October mean
Predicted (cfs)	1.26	18	15.3
Prediction Error	150%	32%	19%

**Basin area: 25.1 sq miles

Figure 9. Observed and modeled streamflow for Coal Creek.



Data Value to Resource Management

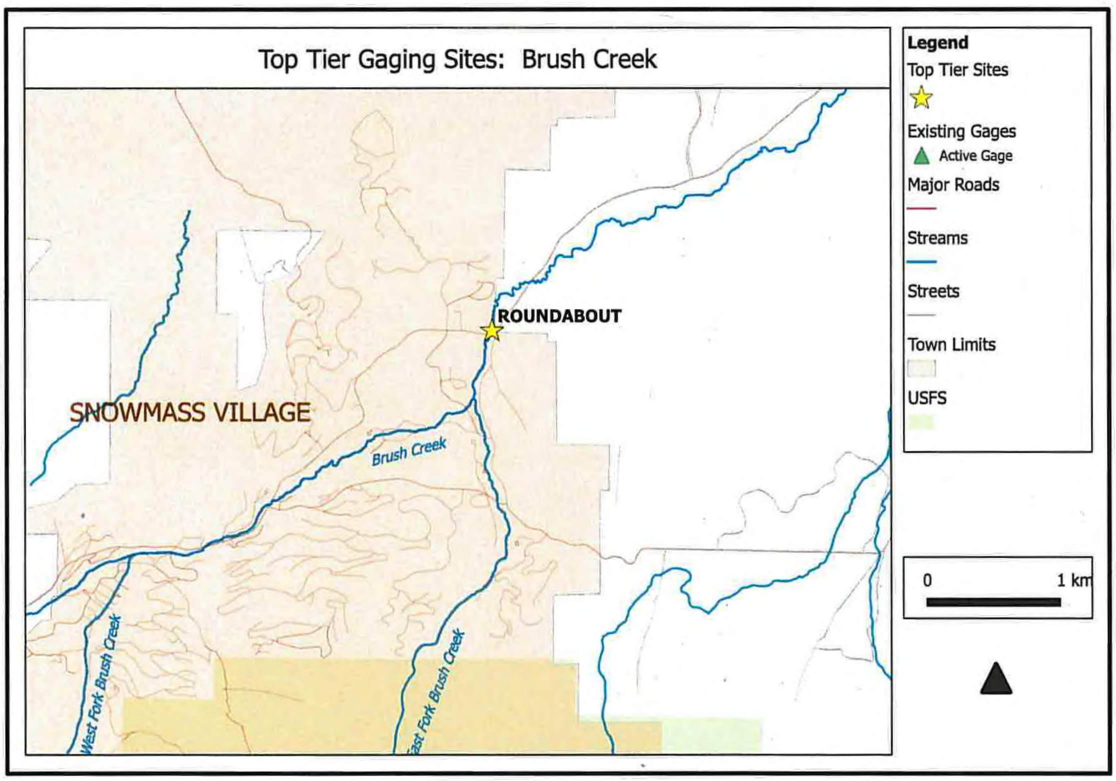
The analysis conducted here indicated that available modeling approaches predicted 2012 flow conditions in a satisfactory manner; however, the large error associated with the modeling results suggest that this may not be a reliable approach for characterizing the hydrological behavior of Coal Creek in the future. Furthermore, modeled data do not provide the continuous streamflow record needed to estimate sediment loading to the Crystal River. Understanding year-round flow characteristics of Coal Creek will be vital to planning and monitoring success in restoration activities. Accurate flow data accompanied by water quality sampling can help elucidate the effects of remediation and management activities on hydrograph behavior and on associated water quality conditions and trends.

Brush Creek below Snowmass Resort

Location

Streamflow monitoring on Brush Creek occurred at the roundabout near the Snowmass Club (the intersection of Brush Creek Road and Highline Road) at the following coordinates: N 39^{0}13'31" W 106^{0}55'15". This location captures the combined flow of the east and west forks of Brush Creek, as well as the outflow from the Town of Snowmass Village wastewater treatment plant. Trans-basin water diversions from East Snowmass Creek augment Brush Creek to support municipal and residential supplies, and winter-time snowmaking. Brush Creek was provisionally 303(d) listed in 2012 for Impaired Aquatic Life. Although USFS and River Watch (via RFC) water quality monitoring continues on Brush Creek, long term flow data is unavailable. Enhancing the availability of streamflow data on Brush Creek is of interest to stakeholders such as RFC and the Snowmass Water and Sanitation District.

Figure 10: Location map for Brush Creek site.



Analysis Approach

Streamflow data from Brush Creek is sparse. This analysis utilized the USGS StreamStats program to estimate hydrograph characteristics, provide context for the 2012 observations, and determine the effectiveness of existing modeling approaches at characterizing streamflow conditions. Notably,

regression models like StreamStats have limited utility in watersheds like Brush Creek, due to the confounding effects of human 'plumbing' of the stream and river systems. StreamStats generated three statistics related to modeled low flow conditions at the drainage point corresponding to the measurement location used to collect the 2012 data. The generated statistics included the M7D10Y, Q9, and Q10. The M7D10Y statistic represents the 7 day average low flow corresponding to an event with a one in ten year return interval. The Q9 and Q10 statistics estimated the mean monthly flows for September and October. Measured flows compared reasonably well to the estimated monthly mean streamflows, although flows were consistently over-estimated by the model. Observed streamflows were much greater than the M7D10Y statistic (i.e. the estimated 10 year low flow) of 0.27 cfs. Possible explanations for this result include both the large model estimation error and the fact that Brush Creek receives trans-basin water augmentation which elevates streamflows above conditions expected in drought year.

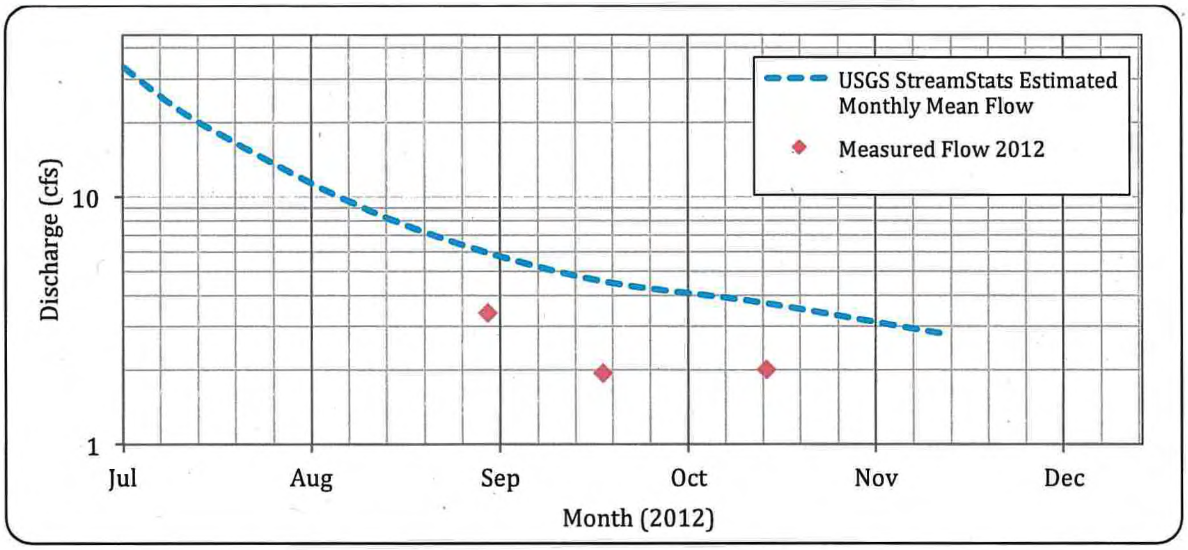
Table 6. Measured flows and USGS StreamStats modeled flows for Brush Creek.

Date	Observed Streamflow (cfs)
8/31/2012	3.4
9/19/2012	1.9
10/16/2012	2.0

StreamStats Model**	10 Year Low Flow	September mean	October mean
Predicted (cfs)	0.27	4.77	3.74
Prediction Error	150%	32%	19%

**Basin area: 10.4 sq miles

Figure 11. Observed and modeled streamflow for Brush Creek.



Data Value to Resource Management

The analysis conducted here indicated that available modeling approaches predicted 2012 flow conditions in a satisfactory manner; however, use of regression based approaches to modeling streamflow in Brush

Creek should be approached with extreme caution because the ability of the model to accurately predict hydrological conditions and characteristics is likely confounded by the presences of trans-basin diversions and consumptive water use by the community. Brush Creek is the focus of continuing investigation by multiple stakeholders regarding type, extent, and sources of potential water quality impairment due to the 2012 provisional 303(d) listing. Enhanced availability of streamflow data will inform these efforts and will allow for more accurate determination of constituent loading—critical steps to addressing water quality impairment issues.

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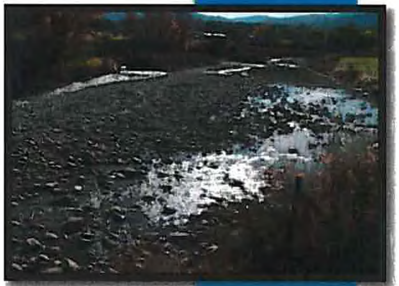
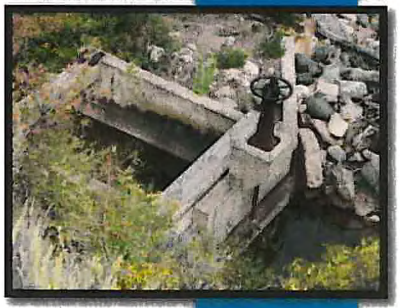
Snapshot Assessment of the Roaring Fork Watershed

A Synoptic Approach to Characterizing Low Flow Conditions on the Crystal and Roaring Fork Rivers in the Autumn of 2012.

February 13, 2013





Prepared For:

PUBLIC COUNSEL
of the rockies

and

ROARING FORK
CONSERVANCY

In Accordance With:

ROARING FORK WATERSHED PLAN

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Acknowledgements

This work was made possible through the generosity and assistance of several parties dedicated to stewardship and thoughtful management of local and State water resources. The Pitkin County Healthy Rivers and Streams Fund and the Colorado Water Conservation Board provided funding for this effort. Private property owners, the Colorado Rocky Mountain School, City of Aspen Open Space, the Town of Carbondale, and Pitkin County Open Space and Trails granted critical access to points along the Crystal and Roaring Fork rivers. GIS layers for figure generation provided by the Pitkin County GIS Department. EcoFlight collected stunning aerial photographs of the lower Crystal River. Amy Beatie, from the Colorado Water Trust and G. Moss Driscoll with Elk Mountain Consulting, LLC played critical roles in developing the project concept. Additionally, we would like to thank Colorado Division of Water Resources Division 5 Water Commissioners, Bill Blakeslee and Jake DeWolfe, for sharing their time and extensive knowledge of the area's rivers and diversion systems.

Executive Summary

The Roaring Fork and Crystal Rivers face numerous issues, including loss of streamflow from trans-basin and local diversions, loss of riparian habitat and floodplain due to development and urbanization, and potential water quality impairment. One of the most significant issues faced in the upper portion of the Roaring Fork River is streamflow depletion. In response to these concerns, Friends of Rivers and Renewables (FORR), an initiative of Public Counsel of the Rockies, and the Roaring Fork Conservancy (RFC) commissioned a study to assess the effects of water diversion activities on streamflow in the Roaring Fork Watershed as they relate to Instream Flow (ISF) water rights held by the Colorado Water Conservation Board (CWCB).

This assessment provides a clearer picture of those sections of the Roaring Fork and Crystal Rivers particularly vulnerable to degradation of stream health from lack of streamflow and excessively warm water temperatures. The study aims to:

1. Help local and state resource managers better understand the relationship between the area's human and natural water systems;
2. Provide scientifically credible data to inform discussions with water right holders and the local communities designed to identify, discuss and, where appropriate, implement creative water conservation solutions;
3. Communicate to the public the status of river health and integrity in the Roaring Fork and Crystal watersheds as it relates to streamflow depletion; and
4. Identify 'pinch' points of low flow in the river most likely to impair longitudinal hydrological and ecological connectivity.

The assessment presented here grew from current efforts by public, private, and government stakeholders in the greater Roaring Fork watershed to explore the way that human 'plumbing' affects the area's rivers. Streams and rivers are vital drivers of local recreation-based economies and are critical to the high quality of life enjoyed by area residents. Yet, the current demands placed on water resources in the Roaring Fork Watershed may exceed their capacity to provide important goods and services to both residents and wildlife.

Two reaches were selected for this assessment, the Roaring Fork River through the City of Aspen, and on the Crystal River from Avalanche Creek to the confluence with the Roaring Fork. A synoptic sampling approach was used to characterize upstream-downstream variability in streamflow as it is affected by tributary inputs and diversion outflows. A synoptic assessment provides a 'snapshot' of longitudinal patterns in streamflow by collecting discharge measurements at many locations, bracketing inflows and outflows to the river, over a short time period. The complex hydrological data generated by this assessment is presented in this report in an impactful and easy to interpret format.

The upper Roaring Fork River was found most vulnerable to low flows in the segment located near the City of Aspen between the Aspen Club and the confluence with Castle Creek. In July, diversions depleted incoming streamflow on this section by 80%. Several miles of the Crystal River between Thompson Creek and Prince Creek are particularly prone to de-watering. September flows at several locations on this

segment were so low that they were nearly un-measurable. These conditions persist from the mouth of Crystal Canyon to outlying subdivisions in Carbondale. Further investigation showed that river segments experiencing extreme low-flow conditions gained heat at a faster rate than other segments, sometimes achieving water temperatures known to be detrimental the region's highly-valued trout fishery.

Information in this assessment intends to enhance understanding of the location and magnitude of human impacts to local waterways. The Roaring Fork and Crystal River provide multiple economic, social, and environmental values to human and wildlife communities in the Roaring Fork Watershed. Faced with the many pressures created by growing local population, increasing Front Range demands on trans-basin supplies, and the effects of climate change on Rocky Mountain water yields, the challenge of managing rivers in a way that meets the needs of human communities without causing considerable impact to ecological function is greater than ever. In order to effectively manage these resources over the long term, relevant and timely information is required by the public at large, natural resource managers, water rights holders, policy makers and advocacy groups.

Purpose Statement

The Roaring Fork and Crystal Rivers face numerous issues, including loss of streamflow from trans-basin and local diversions, loss of riparian habitat and floodplain due to development and urbanization, and potential water quality impairment from a variety of sources (Clarke et al, 2008). One of the most significant issues faced in the upper portion of the Roaring Fork River is streamflow depletion. The Independence Pass Transmountain Diversion System diverts nearly 40% of the annual yield in the upper reaches of the Roaring Fork to augment supplies for Front Range users (Clarke et al, 2008). Additional water diversions near the City of Aspen further deplete streamflow to serve local municipal and irrigation needs. Over-appropriation of water rights on the nearby Crystal River produces a system that frequently fails to fulfill existing water right allocations or meet recommended flows for the maintenance of ecological integrity. A study of Crystal River irrigation diversions identified shortages at some time during the summer irrigation season in approximately one quarter of all years since 1955 (Clarke et al, 2008). In 2012, American Rivers named the Crystal River as one of 'America's Most Endangered Rivers' due to the impacts that proposed dams and water supply projects portend for the waterway (American Rivers, 2012). Changes in climate, population growth accompanied by growing consumptive use needs, and anticipated synergies between changes in water quantity and water quality suggest that patterns of flow depletion in the Roaring Fork Watershed will continue to be an issue of concern for many years to come.

The 2012 Water Year brought exceptionally dry conditions to the Central Rockies region of Colorado. A particularly thin snowpack produced very low flow in streams and rivers throughout the region by mid-summer. Subsequent impacts to water quantity from municipal and agricultural water diversions were particularly visible to residents or the Roaring Fork Valley as their effects were exaggerated by drought conditions. Accompanying changes in water quality likely exerted significant stress on the aquatic biota treasured by local residents and relied upon by local recreation-based economies. In response to these concerns, Friends of Rivers and Renewables (FORR) and the Roaring Fork Conservancy (RFC) commissioned a study to assess the effects of water diversion activities on streamflow in the Roaring Fork Watershed as they relate to Instream Flow (ISF) water rights held by the Colorado Water Conservation Board (CWCB). Instream flow rights are a non-consumptive use of water that allocates a specific minimum streamflow between two geographic points on a stream to protect ecosystem functions[1]. The commissioned study focuses on the portions of the Roaring Fork River and Crystal River perceived most vulnerable to de-watering and extreme low flow conditions.

This assessment intends to provide useful information to land owners, water rights holders, resource managers, policy makers, and advocacy groups as they strive to implement innovative conservation and resource management solutions on the streams and rivers of the Roaring Fork watershed. This effort sought to understand how various water diversions, return flows, and tributaries affect the discharge of a stream on a longitudinal (upstream-to-downstream) profile. The resulting information elucidates the effects of human 'plumbing' of watershed on streamflow and could, by extension, help predict spatial variation in aquatic community (e.g. fish and macroinvertebrates) health. The data presented here also suggest potential streamflow gauging locations best suited for administration of CWCB ISF Rights on the

[1] For more information about ISF water rights, see the CWCB website: http://cwcb.state.co.us/environment/instream-flow-program

two study reaches. This directly supports the goals of the *Roaring Fork Watershed Stream Gauge Needs Workshop* held in April of 2012. Importantly, this assessment is *not intended as a thorough engineering analysis of the water balance on the study reaches.* Rather, this work provides foundational information useful for targeting and maximizing the efficiency of those more expensive undertakings and for facilitating dialog regarding the effects of consumptive water use in the Roaring Fork Watershed.

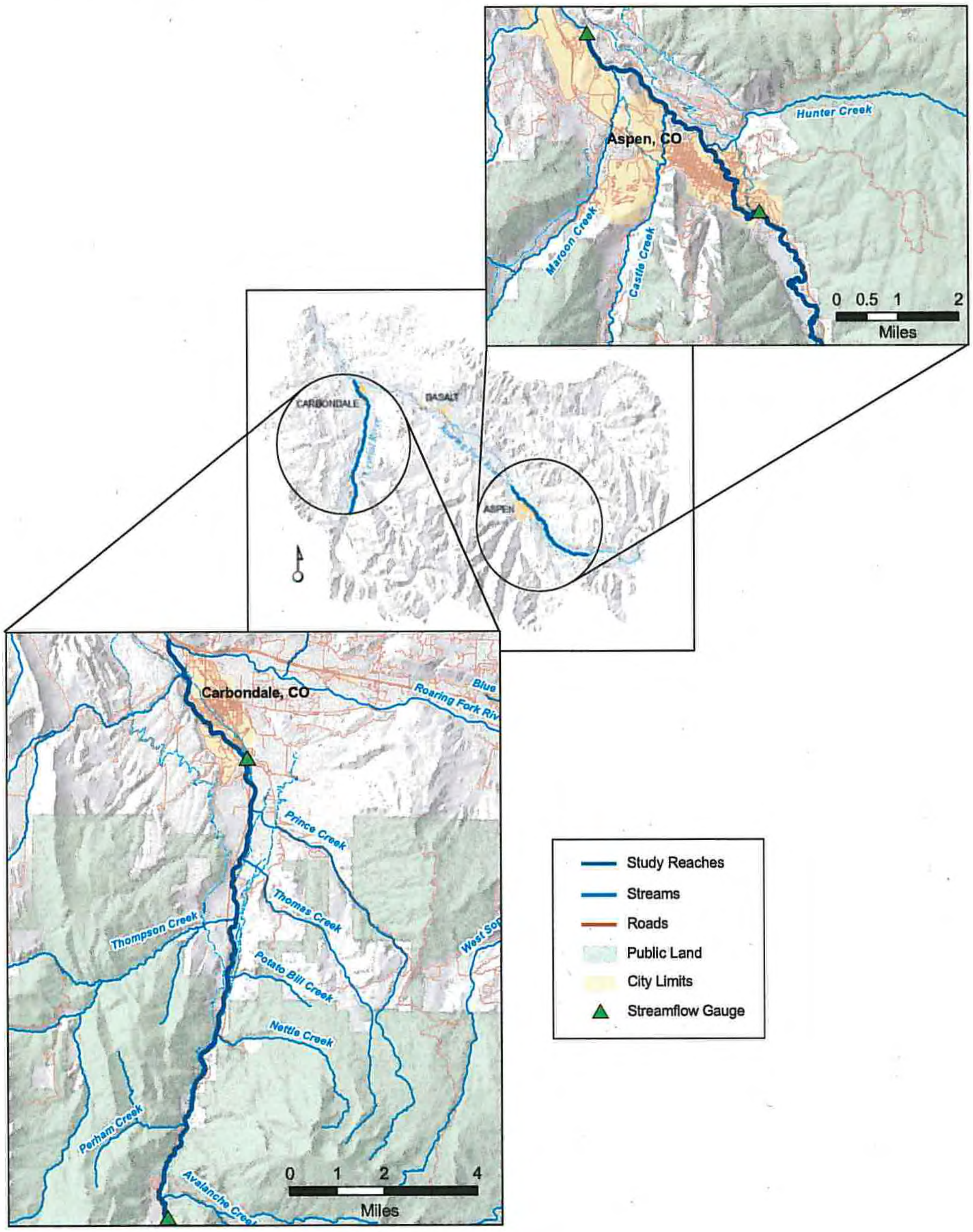


Figure 1. Study Areas

Study Areas

The two reaches selected for this study include: 1) the Roaring Fork River near the City of Aspen, extending from Difficult Creek to the Airport Business Park and 2) the lower Crystal River, extending from Avalanche Creek to the Roaring Fork confluence near Carbondale (Figure 1). Sample sites for streamflow measurements in each stream bracketed significant tributaries and diversions (Table 1). Discharge information was collected at a total of nine sites on the Roaring Fork and 14 sites on the Crystal. In the Crystal River study reach, data were collected manually at 12 sites, while United States Geological Survey (USGS) and Colorado Division of Water Resources (CDWR) gauges provided two additional data points. On the Roaring Fork, six sites were collected manually and USGS and CDWR gauges provided two additional measurement locations. The number of sample locations selected on each reach was limited by the transactional costs of travel to different sites, the actual time required to perform each discharge measurement (upwards of two hours), and the amount of equipment and personnel available to perform measurements.

Table 1. Streamflow observation locations on the Roaring Fork and Crystal River

Station Name	Stream	Latitude	Longitude
USGS Gauge above Avalanche Creek	Crystal	39.26016	-107.23172
USFS Boundary above Sweet Jessup Canal	Crystal	39.27257	-107.22487
Red Wind Point OS	Crystal	29.29029	-107.22487
Above Nettle Creek Rd	Crystal	39.29721	-107.21447
Below Bane & Thomas Ditch	Crystal	39.30463	-107.21304
Above Lowline Ditch	Crystal	39.32619	-107.20905
Thompson Creek Open Space	Crystal	39.33442	-107.20918
At Thomas Rd	Crystal	39.34866	-107.20887
Pitkin-Garfield County line	Crystal	39.36313	-107.20276
DWR Gauge At Fish Hatchery	Crystal	39.37743	-107.20451
RVR South Bridge	Crystal	39.38658	-107.20885
RVR North Bridge	Crystal	39.39277	-107.21888
Above Kaiser & Sievers Ditch	Crystal	39.40289	-107.22878
CRMS Bridge	Crystal	39.40803	-107.22974
USGS Gauge at Stillwater RD	Roaring Fork	39.18007	-106.80216
Aspen Club	Roaring Fork	39.18186	-106.80962
Mill St	Roaring Fork	39.19411	-106.81726
Aspen Institute	Roaring Fork	39.20108	-106.82676
Cemetery Ln	Roaring Fork	39.21104	-106.83991
Airport Business Park	Roaring Fork	39.22207	-106.85717

Tributary creeks dominate inflows to the Roaring Fork River study segment, although several ditch return-flows are also expected to contribute varying rates of flow to the river. The largest tributaries include Hunter Creek, Castle Creek, and Maroon Creek. Headgate diversions into municipal water and irrigation ditch systems comprise the main outflows on this reach (Table 2). Once water enters a given diversion system, it may return to the river or stream as groundwater or ditch return-flows or it may be removed from the system entirely via evaporation or transpiration (Figure 2). Diversion rates vary from one diversion point to the next, and at a single diversion point over the course of the year. Aggregated

diversion rates on the Roaring Fork River study reach may vary from just a few cubic feet per second (cfs) to well over 50 cfs. The most significant diversions of streamflow from the river between the confluence with Difficult Creek and the City of Aspen are the Salvation Ditch, with a decreed diversion right of 59 cfs, and the Wheeler Ditch, with a decreed diversion right of 10 cfs. It is important to note that these numbers are the *decreed rates* listed by the CDWR for a particular diversion. They do not reflect the actual rate of water diverted at the time of this effort. These ditches were generally not diverting their decreed amounts during the sampling period. Possible reasons for diversion rates observed below decreed amounts include: limited irrigation usage needs, time of year, available stream water, senior/junior status within the prior appropriations system, private agreements, and temporal constraints on the water right and constraints from actual available stream flows in 2012. A thorough discussion of this intra-seasonal variation is beyond the scope of this report[2].

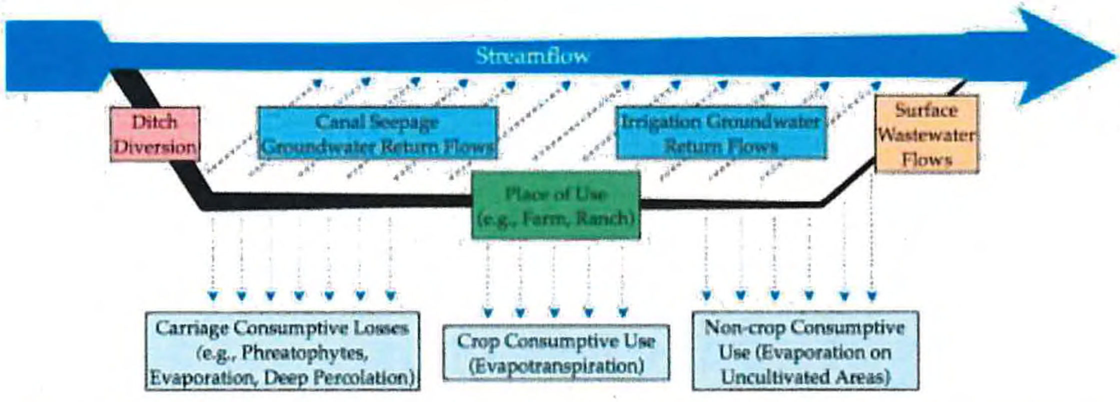


Figure 2. Conceptual model of the water balance on rivers subjected to water diversions for irrigation. The thickness of the blue arrow is proportional to streamflow in the river channel. The thickness of the black line is proportional to the rate of flow in the diversion channel (adapted from *Driscoll, 2012).*

Numerous small tributaries contribute flow to the Crystal River study reach. These include: Avalanche Creek, Potato Bill Creek, Nettle Creek, Thompson Creek, Thomas Creek, and Prince Creek. Generally, these tributaries drain relatively small, low-elevation watersheds. With the exception of Avalanche Creek, they contributed relatively little flow to the Crystal River during this assessment. Several tributaries, such as Thompson Creek and Thomas Creek, experience flow diversion and in September and October were nearly dry or un-measurable at their respective confluences with the Crystal River. Major diversions from the Crystal River occur at twelve locations (Table 3). Decreed rates for these diversions range from 75 cfs at the Sweet Jessup Canal down to 6 cfs at the Helms Ditch. Like the Roaring Fork, discharge measurement locations were selected on the Crystal to bracket tributaries and diversions. Extremely close spacing of diversions or the inability to find a suitable measurement location prohibited individual bracketing diversions and tributaries at several points along the study reach.

2 For more information on this topic, see the Colorado Water Rights information available at the CDWR's web portal: http://water.state.co.us/SurfaceWater

Table 2. Major diversions on the Roaring Fork River study reach (Source: CDWR)

Diversion Name	Decreed Diversion Rate (cfs)
Salvation Ditch	59
Nellie Bird Ditch	4.94
Wheeler Ditch	10

Table 3. Major diversions on the Crystal River study reach. (Source: CDWR)

Diversion Name	Decreed Diversion Rate (cfs)
Sweet Jessup Canal	75
East Mesa Ditch	41.8
Carbondale Ditch	41.2
Lowline Ditch	40.5
Rockford Ditch	35.2
Kaiser and Seivers Ditch	27.1
Bowles and Holland Ditch	23.8
Southard and Cavanaugh Ditch	18.1
Ella Ditch	15.1
Weaver and Leonhardy Ditch	12.4
Bane and Thomas Ditch	6
Helms Ditch	6

Methods

This assessment modeled the two study reaches under the assumption that streamflow may only enter from a surface tributary, and may only leave from a headgate diversion. While this assumption does not strictly match a natural system, it provides a useful working model to understand the effects of human plumbing on the river system. Other natural processes may be responsible for changes in discharge on a particular reach. Interactions between the river channel and the alluvial aquifer are expected to complicate formulation of an accurate water balance on any stream or river reach. Hydraulic head gradients are expected to move water toward or away from the channel throughout each of the study areas, producing changes in measured streamflow that cannot be readily attributed to measured surface water diversions or tributaries. For the purposes of this study, the effects of groundwater-surface water interactions are assumed to be negligible.

Measuring streamflow in the Roaring Fork River above the City of Aspen

Measuring Streamflow

Streamflow (or 'discharge') data was collected on four dates on the Roaring Fork River (7/25/2012, 9/5/2012, 9/18/2012, and 10/16/2012) and on three dates on the Crystal River (9/4/2012, 9/22/2012, and 10/20/2012). Discharge was measured manually using the velocity-area method described in *USGS Techniques and Methods 3-A8* (Turnipseed and Sauer, 2010) with a handheld Sontek Flowtracker® Acoustic Doppler Velocimeter. To compute discharge, a suitable stream cross section was first identified by a combination of a desired location on the study reach, adequate channel shape, and available river access through public right-of-ways or landowner permission. Measuring discharge using the velocity-area method is based on several assumptions, including uniform flow in a downstream direction at an ideally shaped cross section. Several measurement locations on the steep and rocky reaches prevalent in the Roaring Fork and Crystal watersheds were only rated 'fair' to 'good' measurement locations due to excessive turbulence, which increased the potential for measurement error. Even though channel geometry and hydraulics at several locations pushed the boundaries of the methodological assumptions, the employment of thorough quality assurance and quality control procedures ensured that discharge measurements provided accurate estimates of flow. No large thunderstorms were noted in the area on the dates of sampling. Local water administrators affirmed that local diversions were not fluctuating on a short-term (< 1 day) basis on each of the study reaches. These conditions supported the assumption of static or near-static flow during the sampling periods.

Measuring Temperature and Specific Conductance

Three synoptic collections of temperature and specific conductance data occurred during the study to coincide with the streamflow measurements on both study reaches (Roaring Fork River: 9/9/2012, 9/23/2012, and 10/31/2012; Crystal River: 9/7/2012, 9/21/2012, and 11/1/2012). Temperature and temperature-corrected specific conductance data were collected using an Extech II® digital multitmeter. The multimeter was placed in the stream thalweg (or center of flow) until a visual assessment of readings for both temperature and specific conductance showed that they stabilized. These data were collected during clear weather over a time period of 1-3 hours on both the Roaring Fork and Crystal. Observations were planned for clear afternoons to minimize the effects of rapid changes in daytime air temperature near dawn and dusk. Sampling runs began at the top of each study reach and moved in a downstream direction. Data from all sites were collected over a period of approximately 90 minutes on the Roaring Fork study reach and in 2.5-3 hours on the Crystal River. The observed longitudinal temperature and specific conductance signals may be confounded slightly by downstream heat and solute transport, the expected diurnal fluctuations in both parameter values, and the fact that some time lag between subsequent observations was inevitable. Average solute transport rates, the rate of change in either parameter value over the course of a day, and the average sampling lag time between observation locations, may account for some component of the observed signals. However, the relatively rapid pace of sampling runs likely minimized this effect. Thus, the observed profiles are taken here to be accurate representations of point-in-time upstream-downstream patterns in both parameters.

Results and Discussion

Roaring Fork River Streamflow

Interactions between tributary inflows and active water diversions produced persistent longitudinal patterns in streamflow on the Roaring Fork River study reach (Figure 3). Significant diversions below the

Independence Pass Tunnel occur at the Salvation Ditch, which services areas to the northwest of Aspen, and the Wheeler Ditch, which supplies municipal water needs. Decreed water rights at the Salvation and Wheeler ditches are 59 cfs and 10 cfs respectively. Streamflow depletions between these two points ranged from 13 cfs (observed on September 18th, 2012) to 20 cfs (observed on July 25th, 2012). The diversion of 20 cfs in July represented 80% of the river's total flow. Streamflow recovered significantly below the confluences with Castle and Maroon creeks on each of the four observation dates (Table 4). The majority of water in Hunter Creek was diverted prior to joining the Roaring Fork. Throughout the observation period, Hunter Creek did not contribute significantly to streamflow in the Roaring Fork River. Evidently, the majority of the observed streamflow in the upper Roaring Fork River downstream of Maroon Creek was sourced from Castle Creek and Maroon Creek.

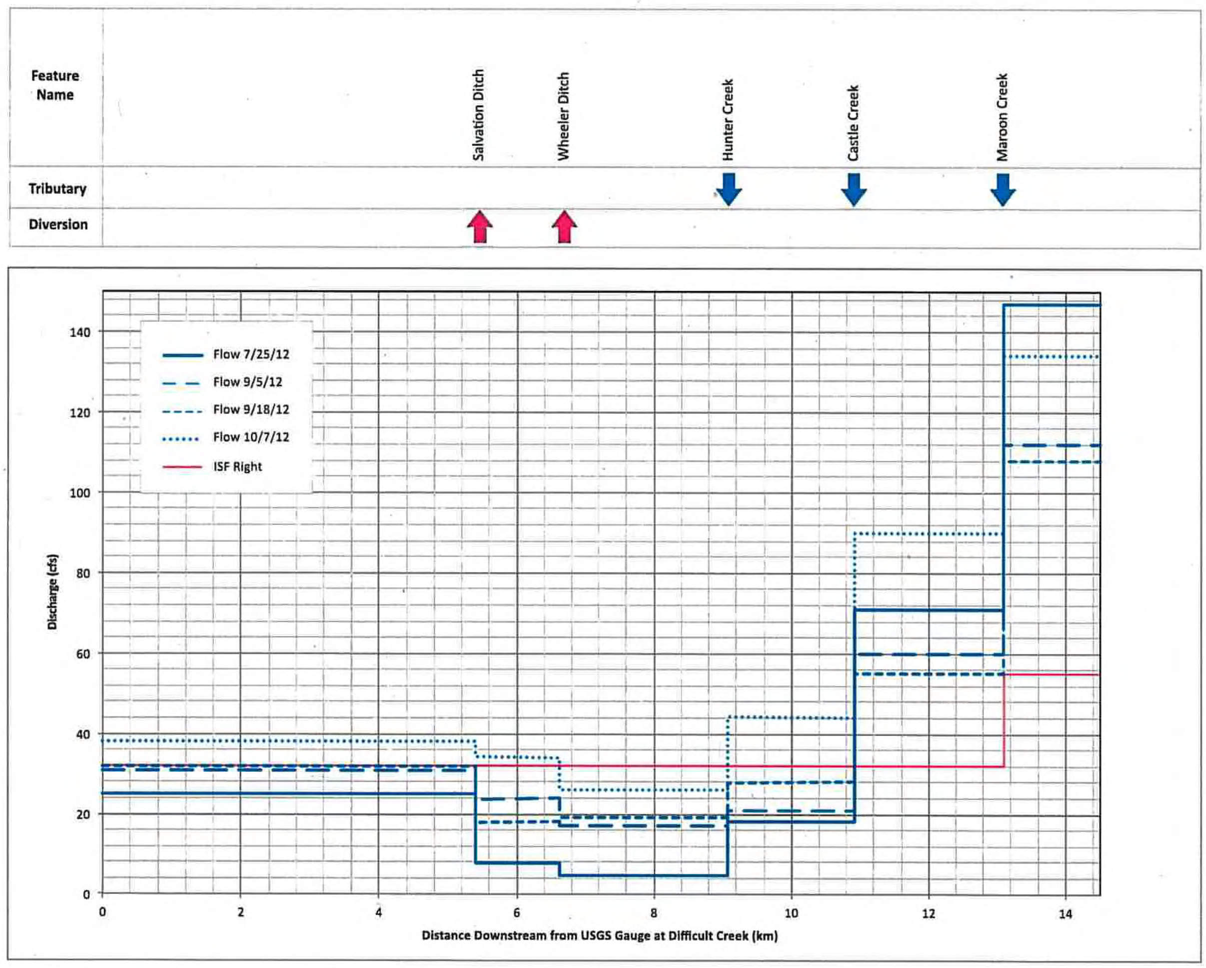


Figure 3. Observed flows on the Roaring Fork River during the study period. Profile confirms that the most de-watered section of the river extends from below the Salvation and Wheeler ditches to the confluence with Castle Creek. This figure plots longitudinal changes in streamflow under the assumption that changes in discharge occur at discrete locations where the river experiences tributary inflows or diversions.

Table 4. Observed streamflow on the Roaring Fork River study reach during three data collection campaigns in September and October of 2012. Data collected during a July 2012 pilot study also displayed.

Site Description	ISF Right (cfs)	Observed Discharge (cfs)			
		7/25**	9/5	9/18	10/16
Above Difficult Creek	32	11	24	26	29
Above Salvation Ditch	32	25	31	32	38
At Aspen Club	32	7.6	24	18	34
At Mill Street Bridge	32	4.7	17	19	26
At Aspen Institute	32	18	21	28	44
At Stein Park	32	71	60	55	90
At CoA WWTP	55	147	112	108	134

****Pilot Study**

During July, the Independence Pass Tunnel was actively diverting water to the Arkansas River Basin. The aggregated effects of this diversion along with local downstream diversions produced the lowest observed streamflow in the Roaring Fork River study reach. Late in the summer of 2012, a collection of agricultural water rights in the Grand Valley area on the Colorado River known as the Cameo Call came into priority, and transmountain diversions through the Independence Pass Tunnel ceased. Roaring Fork River flows prior to the Cameo Call varied from a low of 4.7 cfs near Mill Street in Aspen, to a high of 147 cfs below the combined outputs of Castle and Maroon Creek (Table 4). Cessation of transmountain diversions coincided with measureable increases in streamflow through the most de-watered reach in the City of Aspen.

The Crystal River above Thomas Road observed on 9/24/2012. This extremely low flow condition effectively eliminated upstream-downstream hydrological (and ecological) connectivity.

Crystal River Streamflow

An intricate system of diversion ditches and persistent water use needs produced a complex but persistent patter of longitudinal streamflow on the Crystal River (Figure 4). The two September sample collection dates coincided with heavy irrigation use pressure and little thunderstorm activity. Flows ranged from 77 cfs below Avalanche Creek in early September to a low of 1 cfs at Thomas Road in mid-September (Table 5). The upper section of the study reach was relatively unaffected by diversions and consistently produced the highest streamflow. Diversion activity below Avalanche Creek coincided with large reductions in observed streamflow on all three sampling dates.

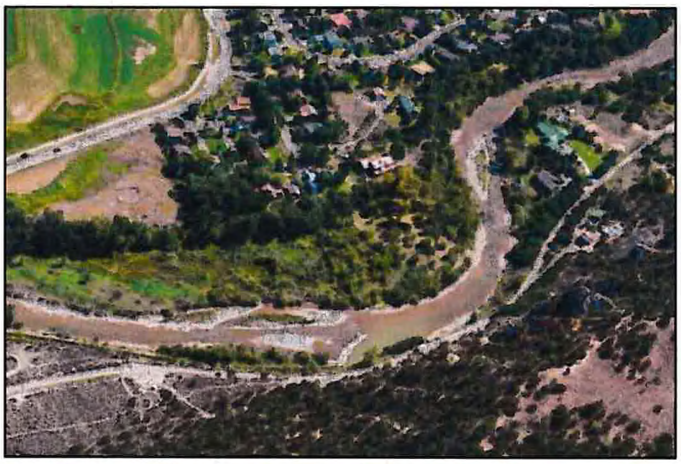
The Crystal River completely de-watered at the end of September near the Garfield-Pitkin County line.

The individual influence of several closely spaced tributaries and water diversions between Thompson Creek and the CDPW Fish Hatchery was difficult to discern. Although several significant diversions occurred, river flows also increased within this section. The increase presumably resulted from the effects of several contributing tributary watersheds, unmapped ditch return flows, groundwater influx from irrigated lands adjacent to the river, and other positive fluxes from the alluvial aquifer. Important tributary creeks on the Crystal River include Potato Bill Creek, Nettle Creek, Thompson Creek, Thomas Creek, and Prince Creek. However, the majority of these creeks experience diversions on their upper reaches. Visual observations of their respective confluences with the Crystal River suggested that they contributed little measurable surface flow during the study period.

Table 5. Observed streamflow on the Crystal River study reach during three data collection campaigns in September and October of 2012.

Site Description	May-Sept ISF (cfs)	Oct-April ISF (cfs)	Discharge (cfs)		
			9/4	9/22	10/20
USGS Gauge above Avalanche Creek	80	40	63	53	53
USFS Boundary above Sweet Jessup Canal	100	60	77	68	66
At Red Wind Point Open Space	100	60	59	58	61
Above Nettle Creek Road	100	60	29	26	38
Below Bane & Thomas Ditch	100	60	29	28	32
Above Lowline Ditch	100	60	31	24	32
At Thompson Creek Open Space	100	60	24	7	30
At Thomas Road	100	60	4	1	28
Above Garfield-Pitkin County Line	100	60	12	8	33
At CDPW Fish Hatchery	100	60	14	8	42
At South Bridge in RVR	100	60	33	24	62
At North Bridge in RVR	100	60	36	21	69
Above Kaiser-Sievers and Southard-Cavanaugh	100	60	44	31	70
At CRMS Bridge	100	60	28	22	56

Dispersed influxes added a small amount of streamflow downstream of the Thomas Creek confluence. Flows showed no significant recovery until below the CDPW Fish Hatchery, where a number of ditch returns began to spill unconsumed water back into the Crystal's main channel. Throughout the RVR subdivision, flows increased somewhat from additional ditch returns. Additional significant diversions occurred in the vicinity of the Colorado Rocky Mountain School near the confluence of the Crystal River and the Roaring Fork River.



Low flow conditions on the Crystal River below the Town of Carbondale (Source: Eco-Flight)

Table 6. Diversions on Study Reach during September and October by reported streamflow rate (Q) and by fraction of total diversions in study area. (Source: provisional data provided by the CDWR)

Diversion Structure	Week of 8/20		Week of 8/27		**Week of 9/11**		**Week of 9/24**		Week of 10/15		**Week of 10/19**		Average	
	Q (cfs)	% total	Q (cfs)	% total	Q (cfs)	% total	Q (cfs)	% total	Q (cfs)	% total	Q (cfs)	% total	Q (cfs)	% total
Sweet Jessup	31	24%	26	18%	26	22%	18	16%	8	8%	9	11%	20	17%
East Mesa	30	23%	29	20%	28	24%	28	25%	29	30%	29	34%	29	26%
Bane and Thomas	0.8	1%	2	1%		0%	3	3%	3	3%	3.85	5%	3	2%
Lowline	12.8	10%	22	16%	11.3	10%	21	19%	4.1	4%	6.02	7%	13	9%
Helms	3.6	3%	6.5	5%		0%	4	4%	3	3%	0	0%	3	2%
Ella	6.23	5%	9.5	7%	8.31	7%	13	12%	9	9%	0	0%	8	6%
Bowles & Holland	4	3%	5	4%	6	5%	4	4%	8.5	9%	6	7%	6	6%
Rockford	7.52	6%	13	9%	12	10%	10	9%	19	20%	17	20%	13	13%
Carbondale	9.2	7%	9	6%	9	8%	8.29	7%	0	0%	0	0%	6	4%
Weaver	4	3%	4	3%	4	3%	3	3%	0	0%	0	0%	3	2%
Southard & Cava.	8	6%	7	5%	6.9	6%		0%	5.4	6%	6	7%	7	6%
Kaiser & Sievers	12	9%	8.5	6%	6.9	6%		0%	7.5	8%	7.5	9%	8	8%

***Bold dates** and associated diversion rates most closely reflect conditions on the 3 observation dates from this study.*

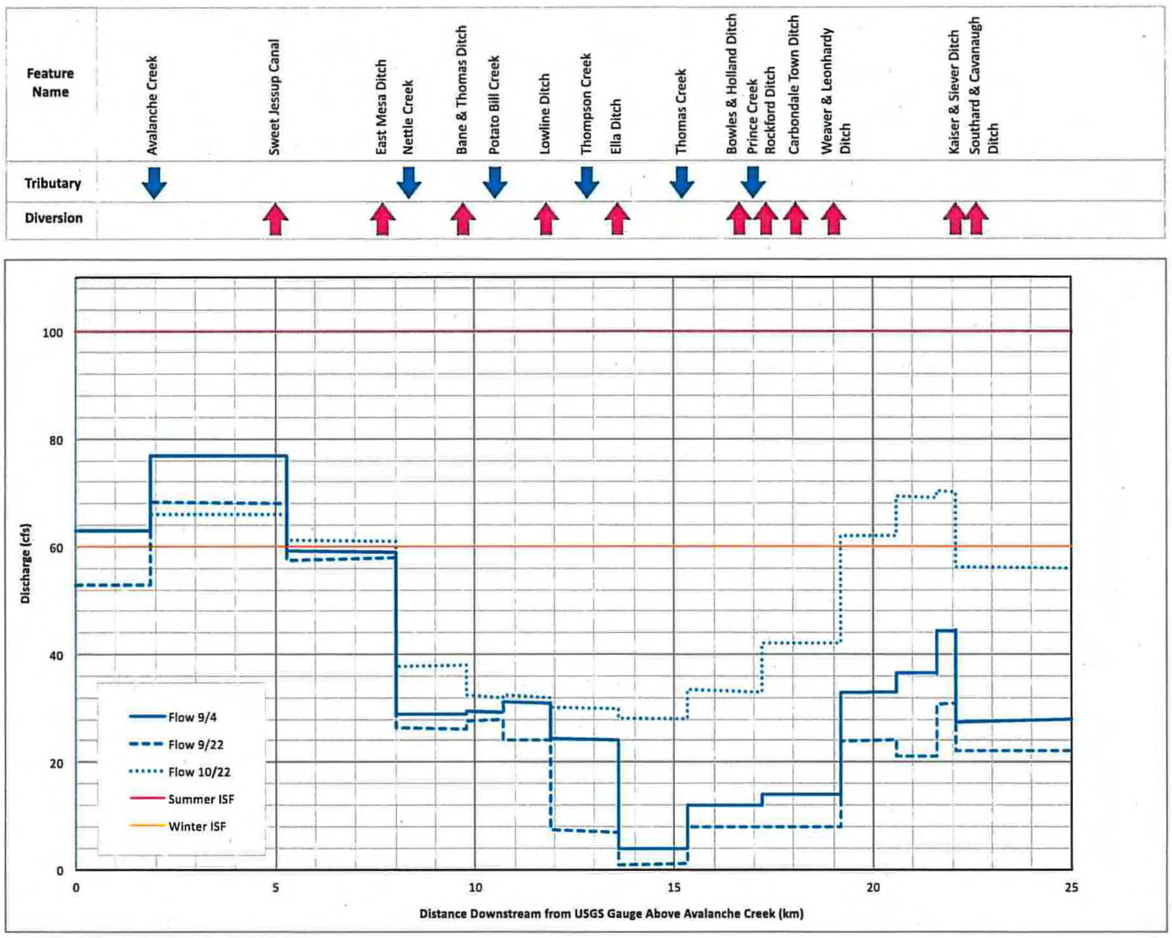


Figure 4. Observed flows on the Crystal River during the study period. Profile confirms that the most de-watered section of the river exists near Thomas Road. This figure plots longitudinal changes in streamflow under the assumption that changes in discharge occur at discrete locations where the river experiences tributary inflows or diversions.

Near the Ella and Helms ditch, the Crystal River flows through Pitkin County's Thompson Creek Open Space parcel. The downstream end of this segment was observed nearly dry on September 22nd. During September, flow in the river channel near Thomas Road was extremely low. River sections exhibiting exceptionally low streamflow, or a complete lack thereof, disrupt hydrological connectivity between upstream and downstream reaches. Importantly, dry river sections prohibit movement of migrating fish during important fall spawning periods. Although an analysis of sedimentation is beyond the scope of this study, visual observation in the flow-depleted reaches revealed extensive fine sediment covering the stream bottom and substrate which can negatively affect macroinvertebrate communities and may render the stream bottom unsuitable for redd construction by trout.

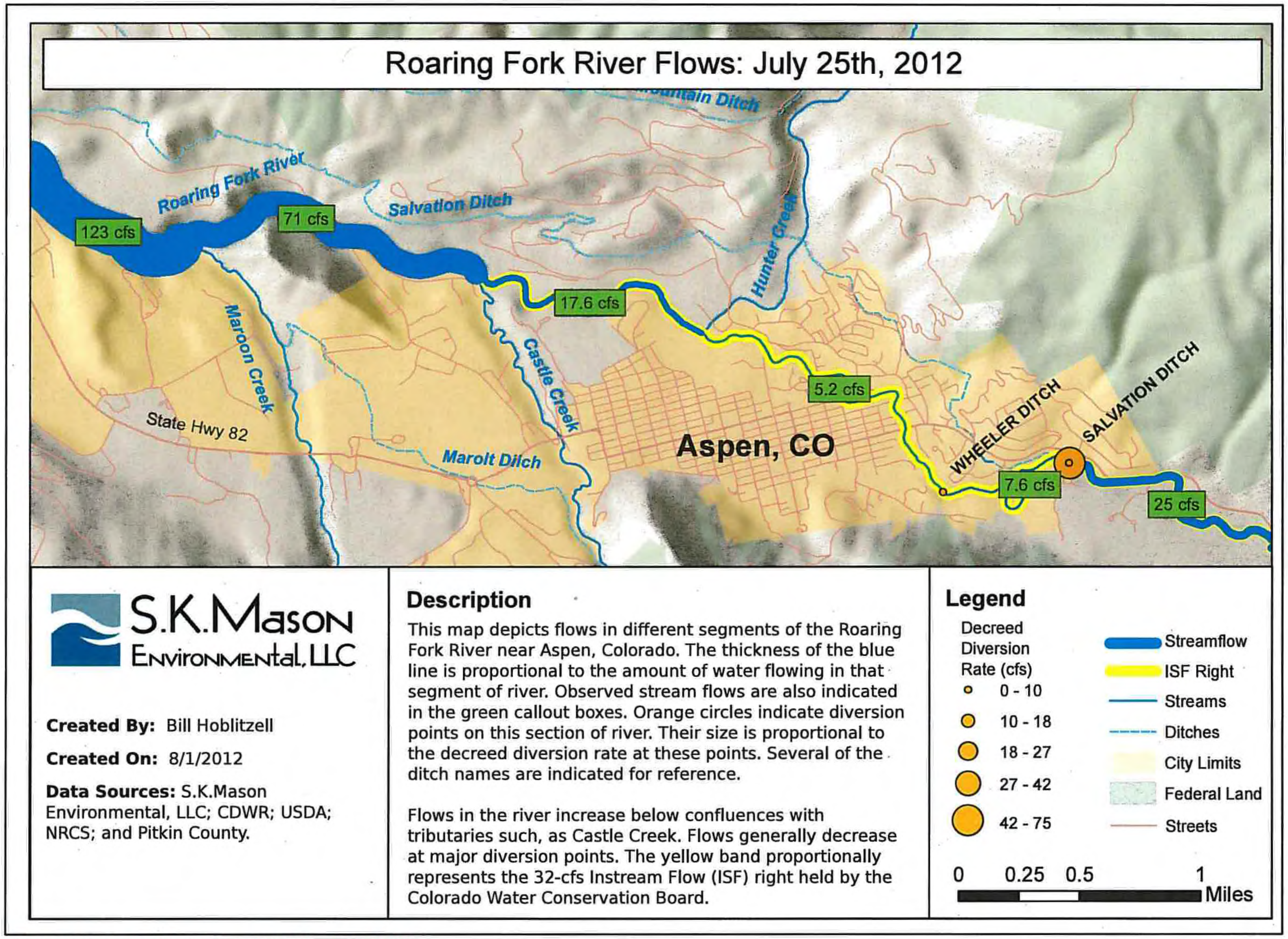
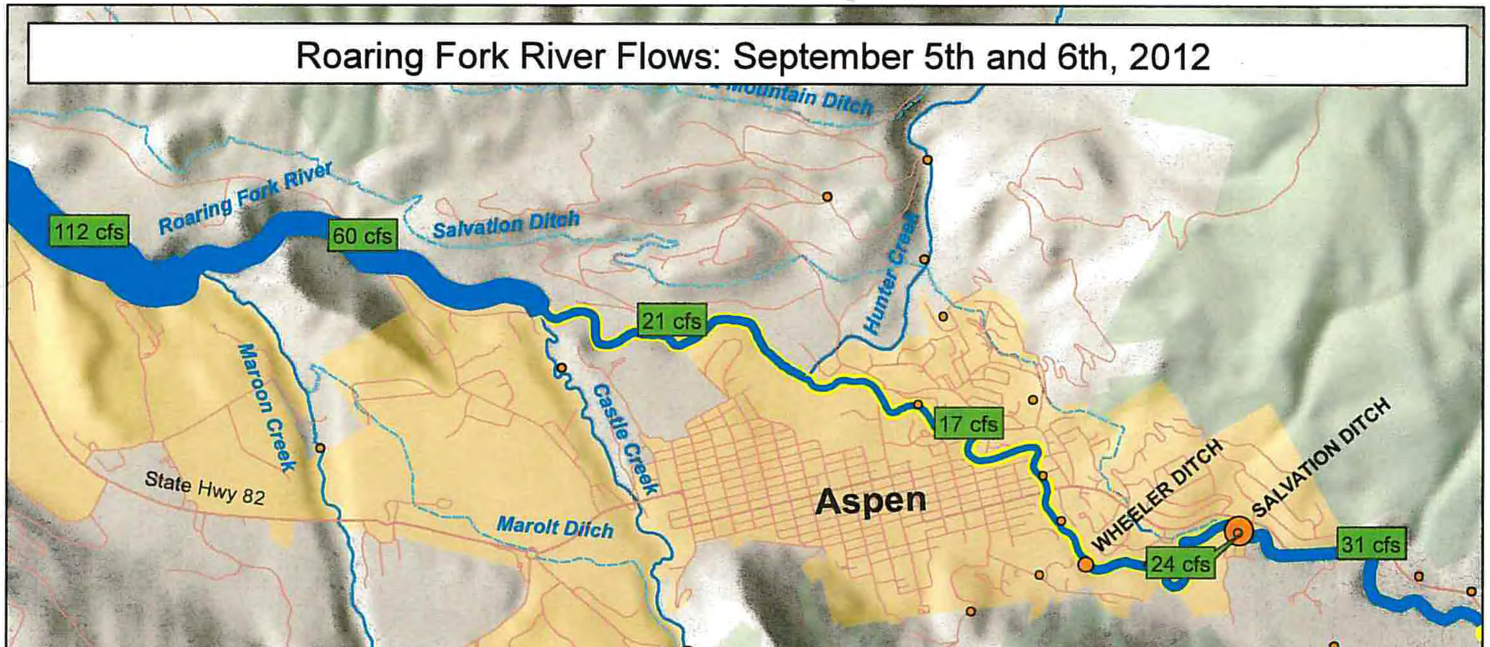


Figure 5. Roaring Fork River Pilot Study, July 25.



S.K.Mason Environmental, LLC

Created By: Bill Hoblitzell

Created On: 11/1/2012

Data Sources: S.K.Mason Environmental, LLC; CDWR; USDA; NRCS; and Pitkin County.

Description

This map depicts flows in different segments of the Roaring Fork River near Aspen, Colorado. The thickness of the blue line is proportional to the amount of water flowing in that segment of river. Observed stream flows are also indicated in the green callout boxes. Orange circles indicate diversion points on this section of river. Their size is proportional to the decreed diversion rate at these points. Several of the ditch names are indicated for reference.

Flows in the river increase below confluences with tributaries such, as Castle Creek. Flows generally decrease at major diversion points. The yellow band proportionally represents the 32-cfs Instream Flow (ISF) right held by the Colorado Water Conservation Board.

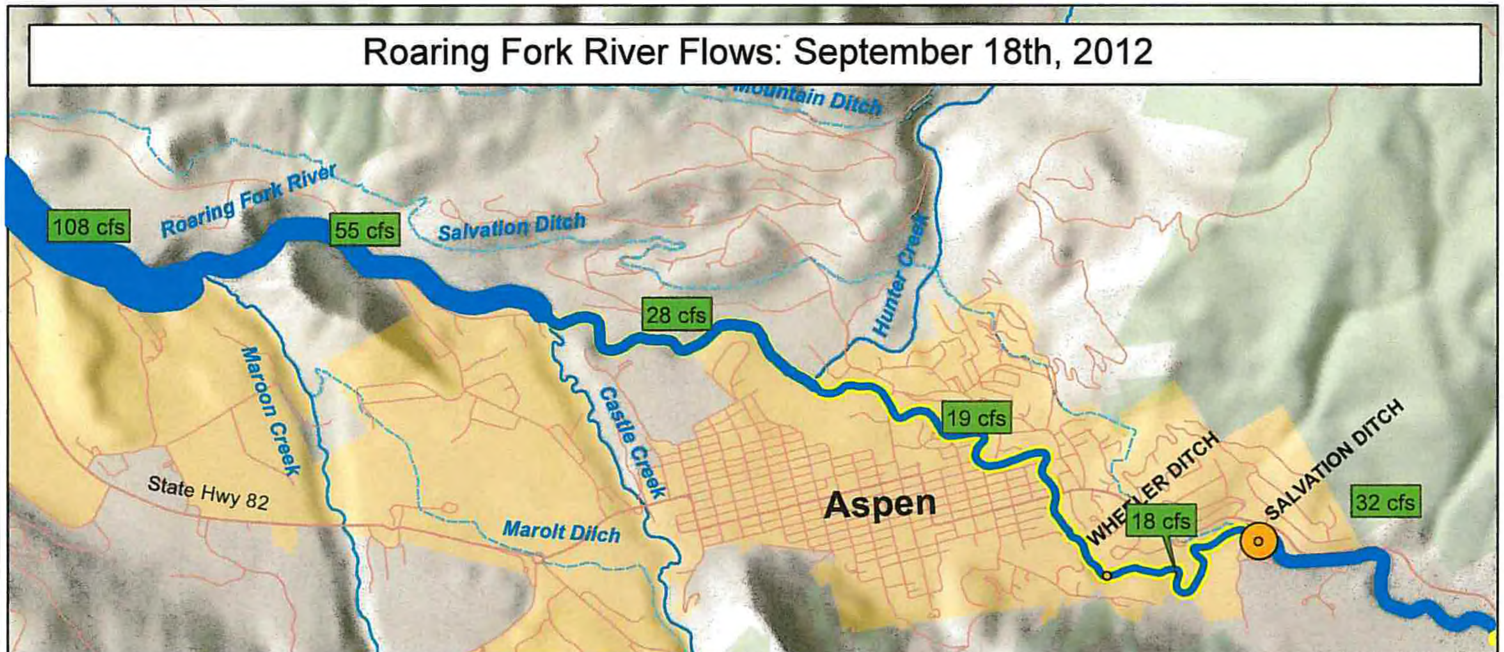
Legend

Decreed Diversion Rate (cfs)
- 0 - 10
- 10 - 18
- 18 - 27
- 27 - 42
- 42 - 75

- Streamflow
- ISF Right
- Streams
- Ditches
- City Limits
- Federal Land
- Streets

0 0.25 0.5 1 Miles

Figure 6. Roaring Fork River, September 5-6.



S.K.Mason Environmental, LLC

Created By: Bill Hoblitzell

Created On: 11/1/2012

Data Sources: S.K.Mason Environmental, LLC; CDWR; USDA; NRCS; and Pitkin County.

Description

This map depicts flows in different segments of the Roaring Fork River near Aspen, Colorado. The thickness of the blue line is proportional to the amount of water flowing in that segment of river. Observed stream flows are also indicated in the green callout boxes. Orange circles indicate diversion points on this section of river. Their size is proportional to the decreed diversion rate at these points. Several of the ditch names are indicated for reference.

Flows in the river increase below confluences with tributaries such, as Castle Creek. Flows generally decrease at major diversion points. The yellow band proportionally represents the 32-cfs Instream Flow (ISF) right held by the Colorado Water Conservation Board.

Legend

Decreed Diversion Rate (cfs)
- 0 - 10
- 10 - 18
- 18 - 27
- 27 - 42
- 42 - 75

- Streamflow
- ISF Right
- Streams
- Ditches
- City Limits
- Federal Land
- Streets

0 0.25 0.5 1 Miles

Figure 7. Roaring Fork River, September 18.

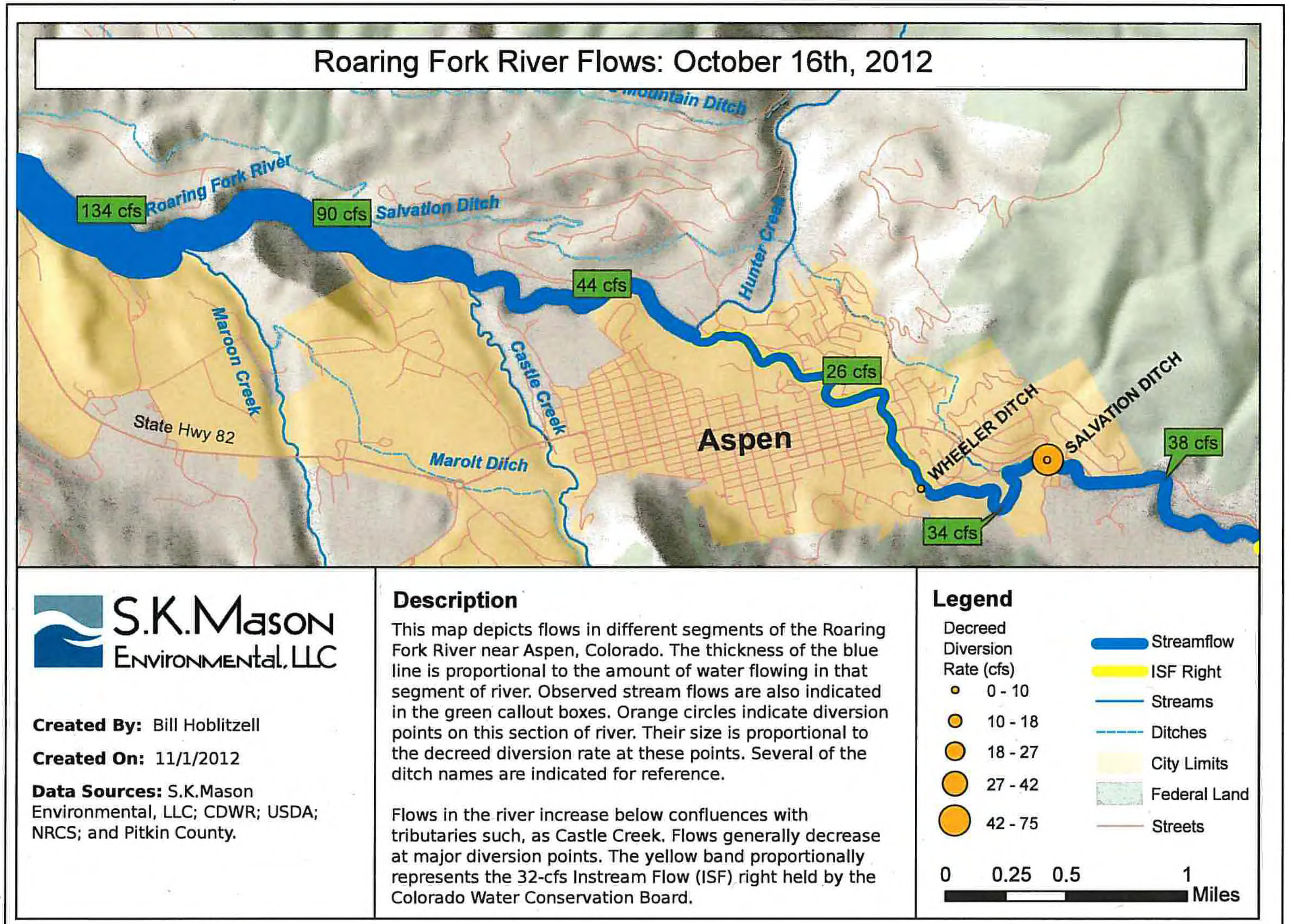
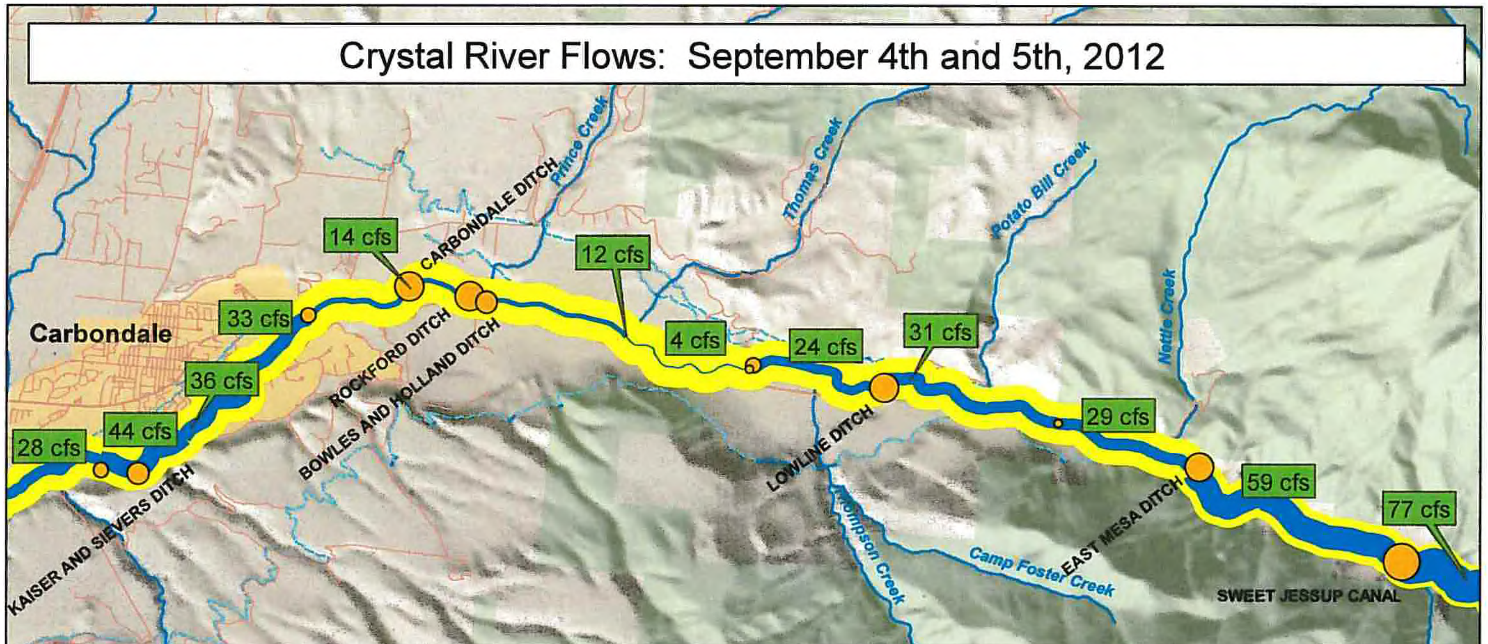


Figure 8. Roaring Fork River, October 16.



S.K.Mason Environmental, LLC

Created By: Bill Hoblitzell

Created On: 11/1/2012

Data Sources: S.K.Mason Environmental, LLC; CDWR; USDA; NRCS; and Pitkin County.

Description

This map depicts flows in different segments of the Crystal River near Carbondale, Colorado. The thickness of the blue line is proportional to the amount of water flowing in that segment of river. Observed stream flows are also indicated in the green callout boxes. Orange circles indicate diversion points on this section of river. Their size is proportional to the decreed diversion rate at these points. Several of the ditch names are indicated for reference.

Flows in the river increase below confluences with tributaries, such as Avalanche Creek. Flows generally decrease at major diversion points. The yellow band proportionally represents the 100-cfs Instream Flow (ISF) right held by the Colorado Water Conservation Board.

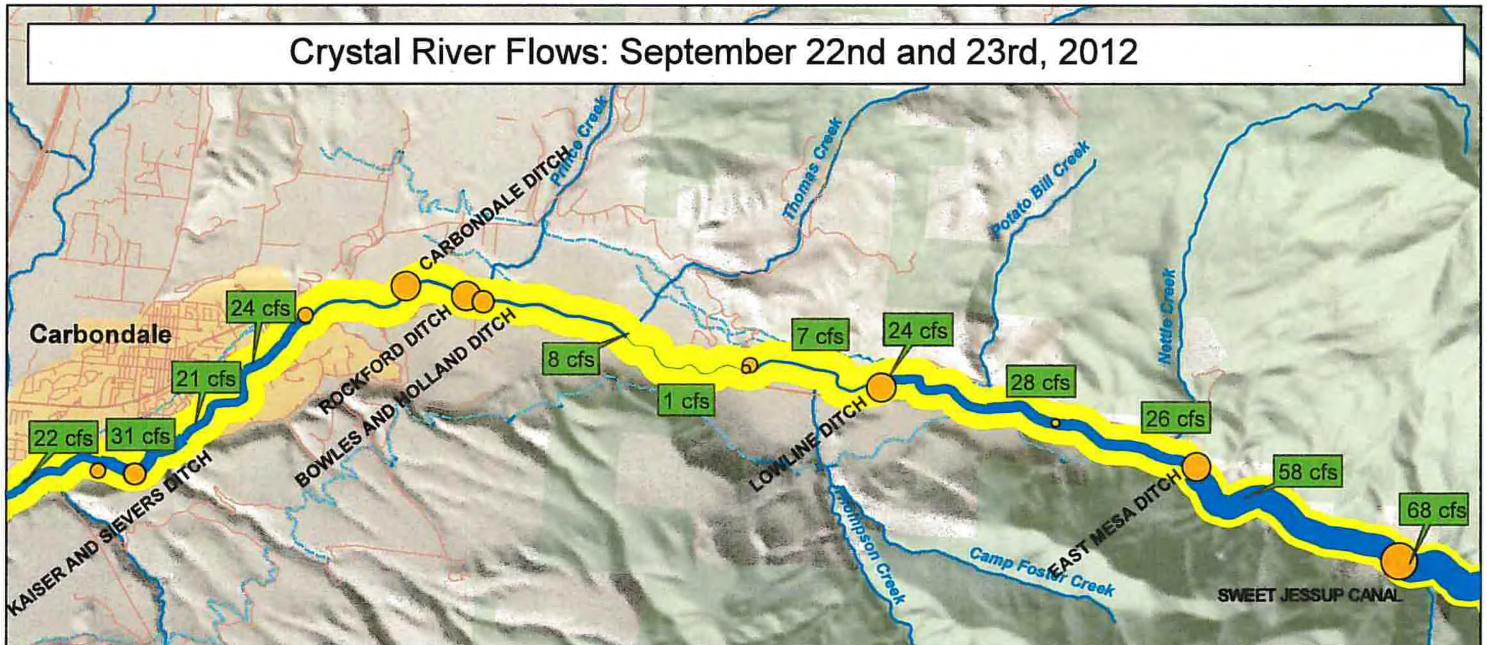
Legend

Decreed Diversion Rate (cfs)
- 0 - 10
- 10 - 18
- 18 - 27
- 27 - 42
- 42 - 75

Streamflow
ISF Right
Streams
Ditches
City Limits
Federal Land
Streets

0 0.5 1 2 Miles

Figure 9. Crystal River, September 4-5.



S.K.Mason Environmental, LLC

Created By: Bill Hoblitzell

Created On: 11/1/2012

Data Sources: S.K.Mason Environmental, LLC; CDWR; USDA; NRCS; and Pitkin County.

Description

This map depicts flows in different segments of the Crystal River near Carbondale, Colorado. The thickness of the blue line is proportional to the amount of water flowing in that segment of river. Observed stream flows are also indicated in the green callout boxes. Orange circles indicate diversion points on this section of river. Their size is proportional to the decreed diversion rate at these points. Several of the ditch names are indicated for reference.

Flows in the river increase below confluences with tributaries, such as Avalanche Creek. Flows generally decrease at major diversion points. The yellow band proportionally represents the 100-cfs Instream Flow (ISF) right held by the Colorado Water Conservation Board.

Legend

Decreed Diversion Rate(cfs)
- 0 - 10
- 10 - 18
- 18 - 27
- 27 - 42
- 42 - 75

- Streamflow
- ISF Right
- Streams
- Ditches
- City Limits
- Federal Land
- Streets

0 0.5 1 2 Miles

Figure 10. Crystal River, September 22-23

S.K.Mason Environmental, LLC

Created By: Bill Hoblitzell

Created On: 11/1/2012

Data Sources: S.K.Mason Environmental, LLC; CDWR; USDA; NRCS; and Pitkin County.

Description

This map depicts flows in different segments of the Crystal River near Carbondale, Colorado. The thickness of the blue line is proportional to the amount of water flowing in that segment of river. Observed stream flows are also indicated in the green callout boxes. Orange circles indicate diversion points on this section of river. Their size is proportional to the decreed diversion rate at these points. Several of the ditch names are indicated for reference.

Flows in the river increase below confluences with tributaries, such as Avalanche Creek. Flows generally decrease at major diversion points. The yellow band proportionally represents the Oct.-April 60-cfs Instream Flow (ISF) right held by the Colorado Water Conservation Board.

Legend

Decreed Diversion Rate (cfs)
- 0 - 10
- 10 - 18
- 18 - 27
- 27 - 42
- 42 - 75

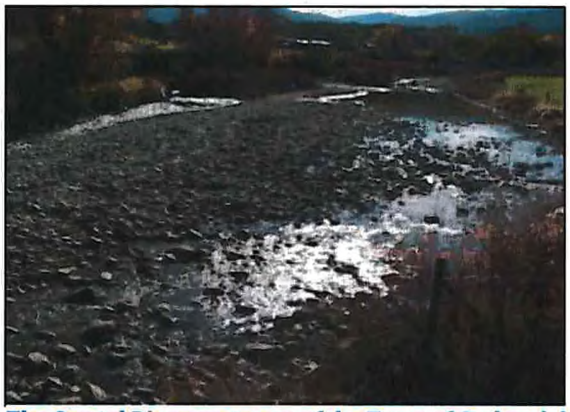
- Streamflow
- ISF Right
- Streams
- Ditches
- City Limits
- Federal Land
- Streets

0 0.5 1 2 Miles

Figure 11. Crystal River, October 20-21.

Temperature Profiles

Water temperature directly affects the myriad biological communities residing in the water column and in the streambed on any river or stream. Critically, as water temperature increases, the amount of oxygen that may be dissolved in it decreases. This, in turn, can place stress on fisheries and aquatic macroinvertebrates. The Colorado Department of Parks and Wildlife (CDPW) identifies 66^0 F (18.9^0 C) as an important temperature threshold beyond which degradation of brown trout fisheries is likely to occur. Other species like brook trout and cutthroat trout are less heat tolerant. A number of factors may affect spatial and temporal patterns water temperature. Variations in the rate at which a stream gains heat may be strongly related to flow; however, they should not be assumed to result from changes in streamflow alone.



The Crystal River upstream of the Town of Carbondale. Return flows on the west side of the river and at the Carbondale ditch provide a cooling inflow to dewatered sections of the Crystal which are subject to rapid heat gain.

The CDPW temperature threshold was exceeded at two locations in early September on the Crystal River. In the most flow-depleted segments (between Thompson and Thomas creeks), observed temperatures in the Crystal River were relatively high during both September sampling dates. The rapid rate at which the river absorbed heat at these locations is reflected in the relatively steep upward slopes of the temperature profiles in the segment (Figure 12). As return flows, tributaries, and assumed groundwater influxes contributed to streamflow below Thomas Creek, water temperatures began to decline. During the final round of post-irrigation season observations, the sharp temperature spike previously observed near Thomas Road did not persist. Citizens participating in the Roaring Fork Conservancy's *Hot Spots for Trout* volunteer monitoring program (www.roaringfork.org) recorded multiple observations of temperatures above the recommended standard of 66^0 F at the Fish Hatchery and Colorado Rocky Mountain School (Appendix B). The highest temperatures were recorded by RFC at these two locations on the Crystal River were as follows: 68°F on August 12 at 6:00PM at the Fish Hatchery and 72.5°F on July 12 at 2:00 PM at the CRMS Bridge.

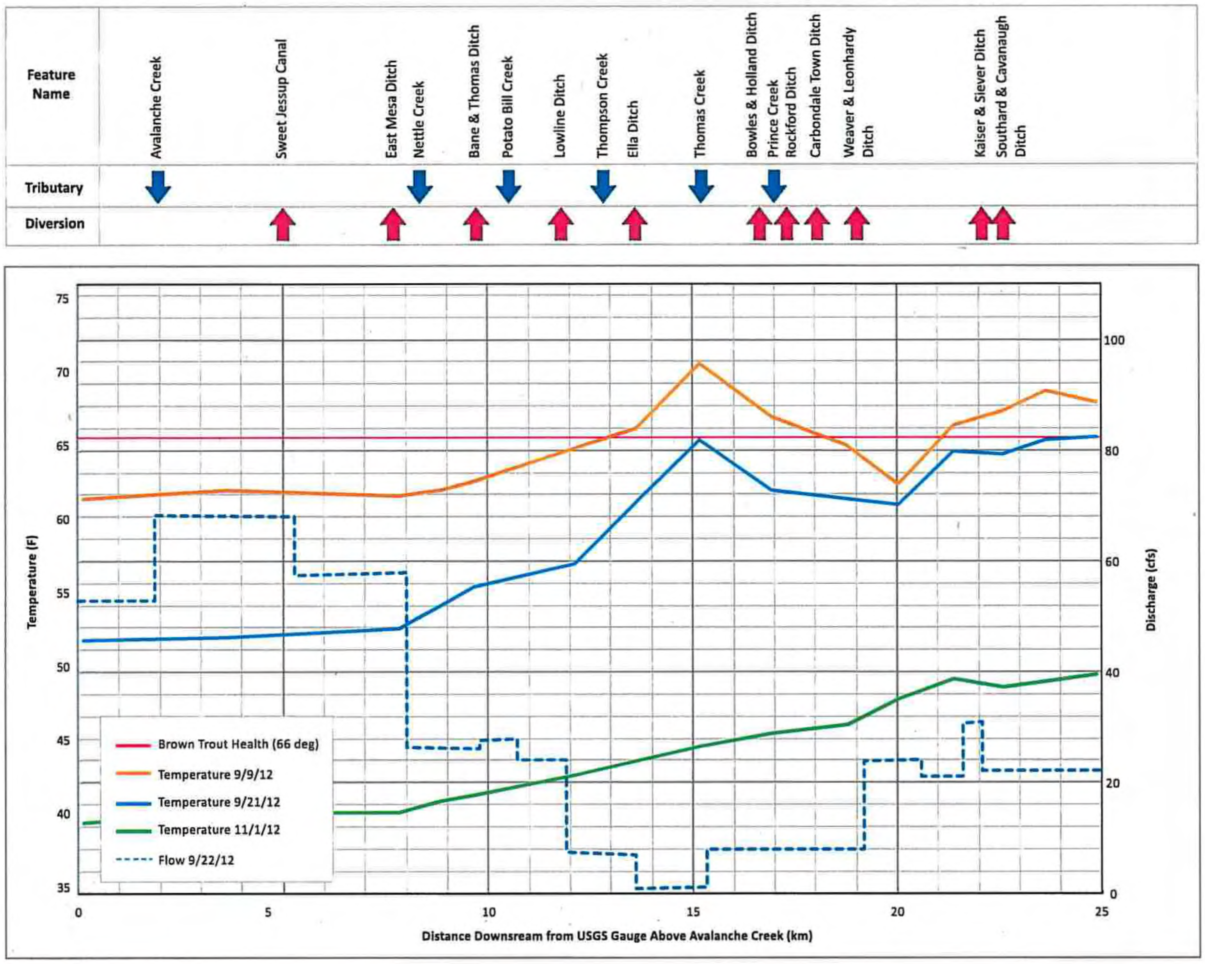


Figure 12. Observed temperatures on the Crystal River. Temperatures rise rapidly as flow decreases, peaking in the area near Thomas Road.

The Roaring Fork study reach did not reach temperature levels stressful to fish during any of the three sampling events (Figure 13). This can be largely attributed to this reach's location at a higher elevation in the watershed. However, prior to collection of data for this study, citizens participating in the Roaring Fork Conservancy's *Hot Spots for Trout* volunteer monitoring program (www.roaringfork.org) found temperatures at or above the recommended standard of 66°F at the Hopkins Street Footbridge, a flow-depleted section of the study reach upstream of Mill Street (Appendix B). These observations were made on 6/30/2012, 7/10/2012, and 7/26/2012. Sections of the river experiencing the lowest flows show the most rapid heat gain as displayed by the slope of the longitudinal temperature profile. Tributary inflows from Castle Creek and Maroon Creek had a visible cooling effect on streamflow in the Roaring Fork River.

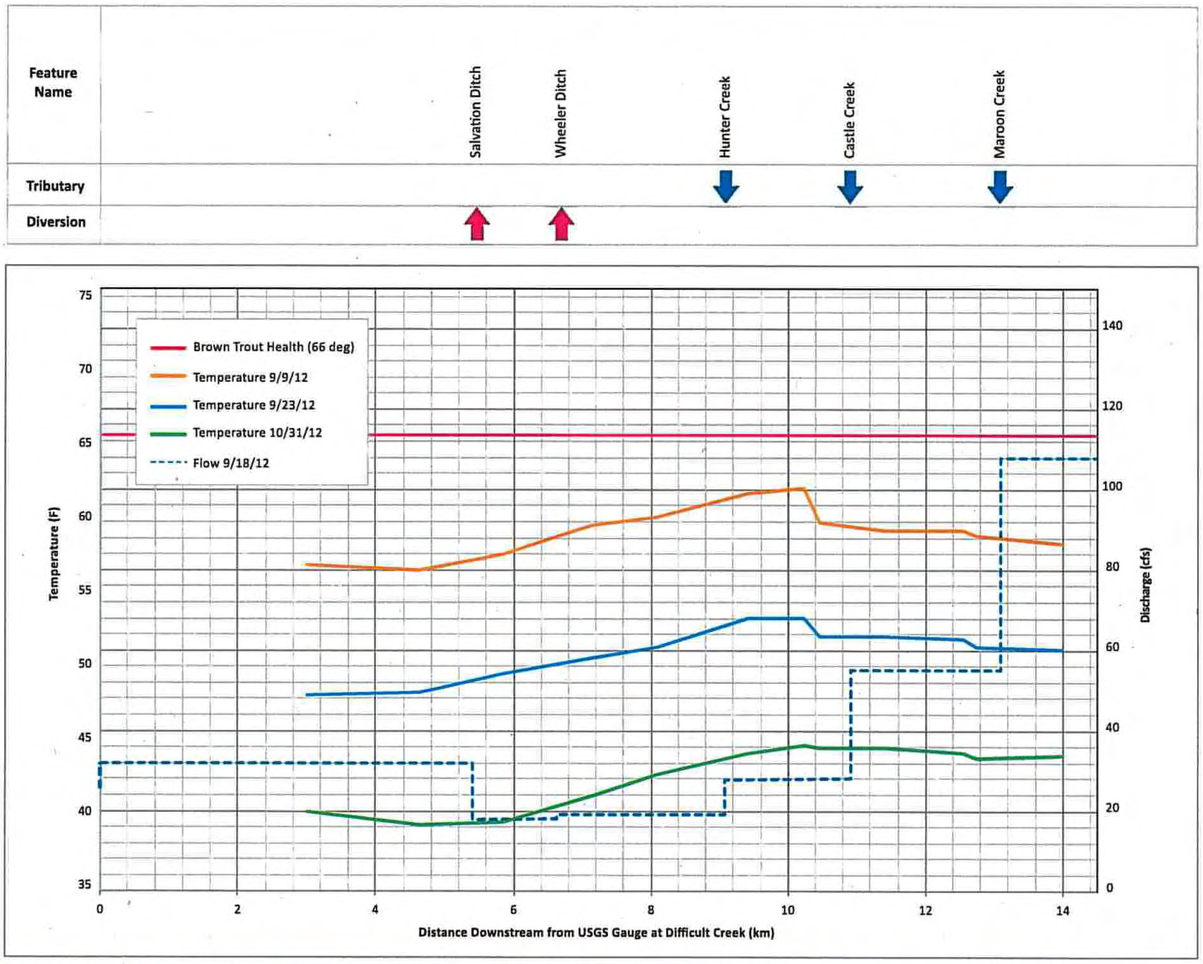


Figure 13. Observed temperatures on the Roaring Fork River near the City of Aspen. Low flow conditions coincide with relatively rapid heat gain.

Specific Conductance Profiles

Specific conductance, also commonly referred to as *conductivity*, is a measure of water's ability to conduct an electrical current. Conductance is a function of the concentration of ionized, or electrically charged, solids in water. Measuring conductance does not allow one to differentiate among sources or relative concentrations of these constituents, however it does serve as a useful proxy measurement for Total Dissolved Solids (TDS). Dissolved constituents may enter rivers from a multitude of sources, including: natural geological weathering, urban runoff from streets and yards, and agricultural runoff laden with nutrients and fertilizers. The spatial variability in TDS can yield important information to water quality monitoring efforts as it may relate to changes in land use or water management activities. High specific conductance is *not* an indicator by itself of poor water quality or pollution, and should not be interpreted as such. Rather, sharp changes in longitudinal specific conductance profiles may inform targeted investigations to determine the sources and relative quantities of constituents contributing to the overall observed pattern.

Water in the upper Roaring Fork River displayed relatively low specific conductance. Conductance increased with downstream distance as the river flowed through the City of Aspen (Figure 14). The observed increase may result from diffuse urban runoff, stormwater drains, and irrigation return flows. A sharp increase in conductance observed below the confluences with Castle Creek and Maroon Creek, suggests that these two tributaries carry relatively large TDS loads. The water quality characteristics of Maroon and Castle creeks produced disproportionately large impacts on the overall water quality characteristics of the Roaring Fork River because the streamflow contributions from the two creeks represented a large fraction of the total streamflow in the Roaring Fork below the City of Aspen. Elevated TDS concentrations in these tributary streams is likely related to natural geological weathering as both tributary watersheds are relatively undeveloped.

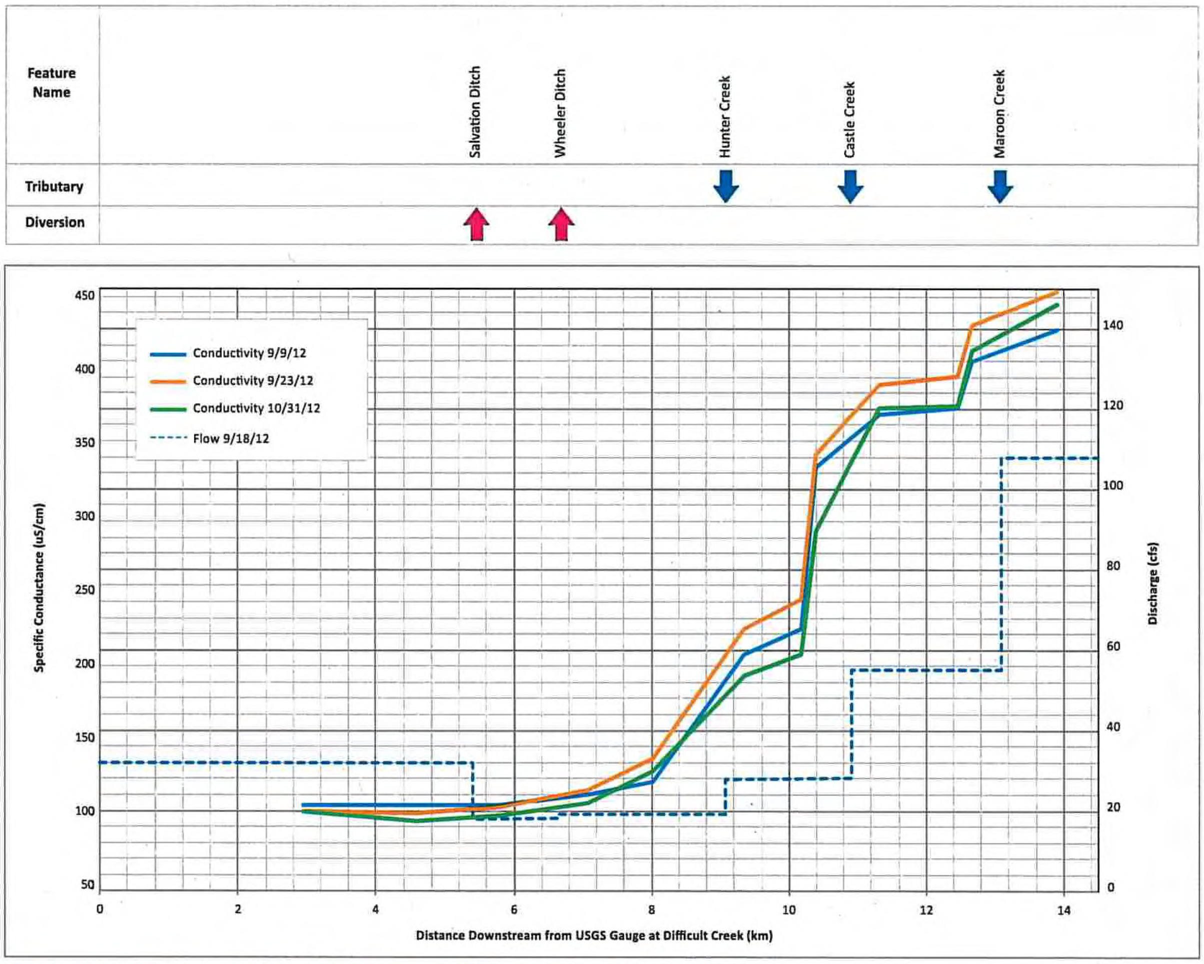


Figure 14. Observed specific conductance profiles on the Roaring Fork River.

Specific conductance remained relatively constant in the upper section of the Crystal River study reach, decreasing slowly through the most dewatered section on the reach (Figure 15). This pattern may be explained by the possibility that a large fraction of the streamflow in the Crystal River below Thompson Creek is contributed from tributaries or groundwater from the alluvial aquifer exhibiting relatively low specific conductance values. Conductance rose lower on the river where flows were likely affected by both groundwater influxes and irrigation diversion return flows. A seasonal trend was evident from early September to later in the fall. Specific conductance increased through September to its highest levels in late October. Specific conductance is generally inversely related to streamflow (e.g. dissolved solids are more concentrated when streamflow is low). As the amount of water diverted from the Crystal River decreased in October, streamflows in the river channel increased at each observation location. Surprisingly, specific conductance also increased—an unexpected trend. Without more observations to characterize inter-annual and inter-seasonal variability, it is difficult to make many conclusions regarding this pattern. However, an early snowstorm and subsequent runoff from snowmelt—which is expected to exhibit elevated conductance values—may have played an important role.

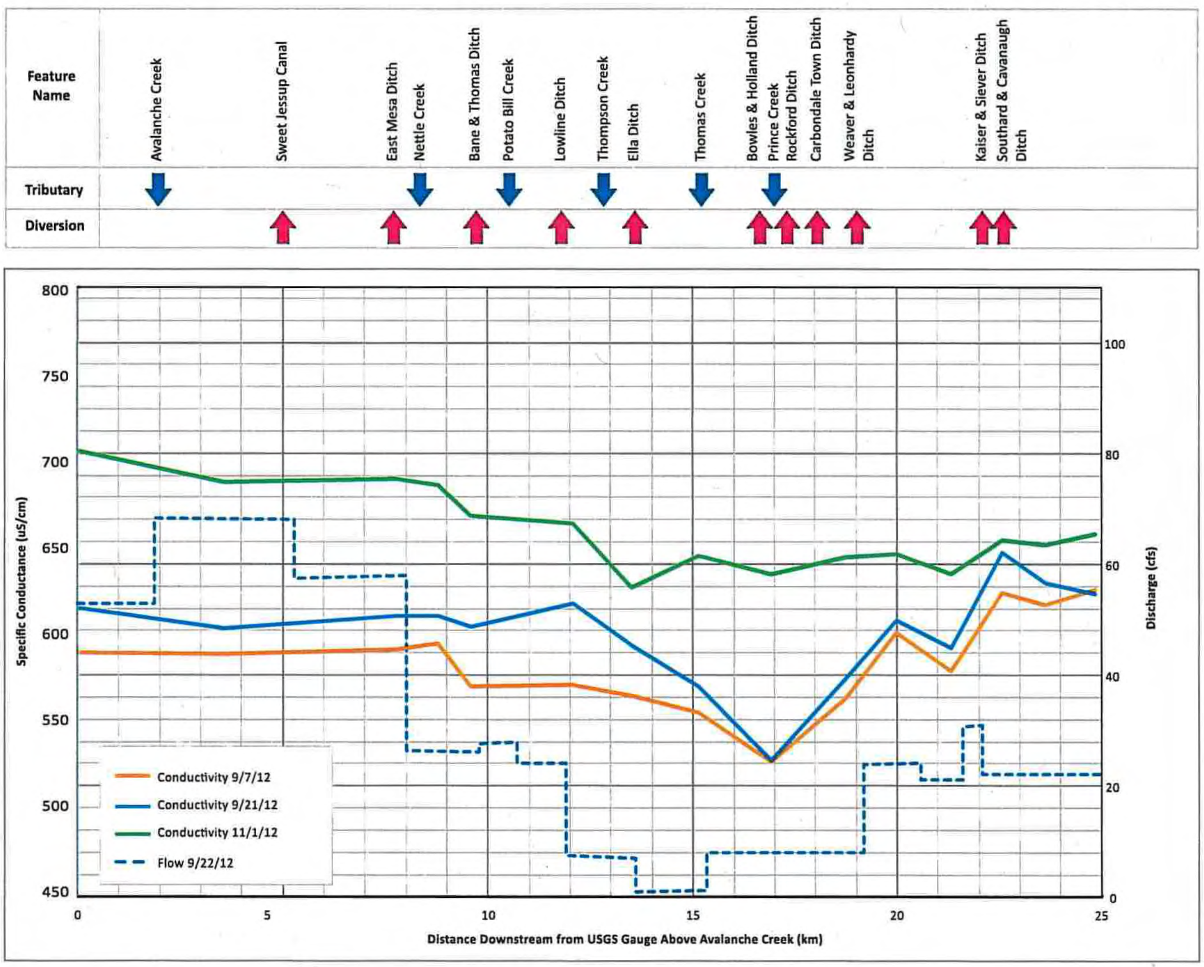


Figure 15. Observed specific conductance profile on the Crystal River.

Implications and Future Directions

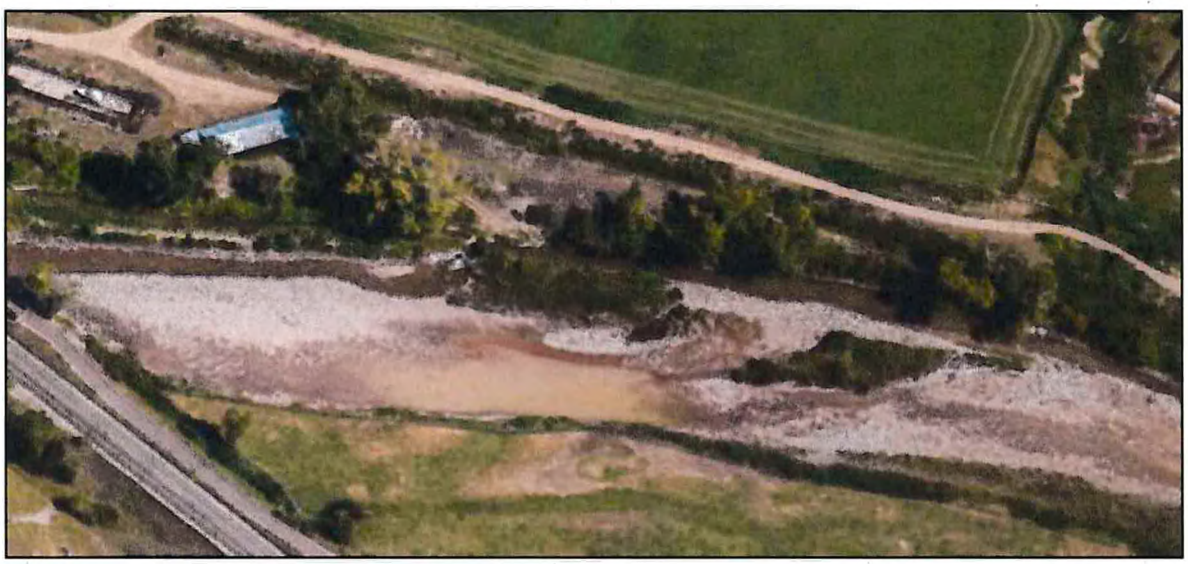
This work provides a clearer picture of those sections of the Roaring Fork and Crystal Rivers particularly vulnerable to degradation of stream health from lack of streamflow and excessively warm water temperatures. The study aims to:

5. Help local and state resource managers better understand the relationship between the area's human and natural water systems;
6. Provide scientifically credible data to inform discussions with water right holders and the local communities designed to identify, discuss and, where appropriate, implement creative water conservation solutions;
7. Communicate to the public the status of river health and integrity in the Roaring Fork and Crystal watersheds as it relates to streamflow depletion and ISF rights; and
8. Identify 'pinch' points of low flow in the river most likely to impair longitudinal hydrological and ecological connectivity.

The Roaring Fork River near the City of Aspen and the Lower Crystal River are understood to be particularly vulnerable to streamflow depletion. The most flow-depleted segment of the Roaring Fork River in the fall of 2012 was found between the Salvation and Wheeler ditches and the confluence with Castle Creek. The patterns in longitudinal streamflow observed during the study presented here may are probably typical during any dry year when upstream diversion rights are exercised upstream. However, no regular streamflow monitoring exists on this segment to accurately document the frequency or magnitude of this occurrence or effectively administer the CWCB ISF right on this section of river. The segment of the lower Crystal River between the Ella and Carbondale/Rockford ditches encompasses the most flow-depleted section of this river. Near complete dewatering of the stream channel was observed through much of September at Thomas Road and near the Garfield/Pitkin County line. This section is likely vulnerable to similar low streamflow conditions in most dry years. The nearest streamflow monitoring site able to document these events is located several miles downstream at the CDPW Fish Hatchery. This streamflow gauge does not fully capture the severity of flow depletion on the Crystal River because it is located below several irrigation return flows, which increase streamflow in the river channel. As determined in this assessment, more flow-impaired reaches exist upstream of this location. These could provide more ideal locations for a stream gauge site intended to monitor low-flow conditions and corresponding water quality characteristics.

Dewatered rivers can negatively impact aquatic communities like trout fisheries (an important economic driver of the area's tourism industry) and recreational amenities that support the exceptional quality-of-life valued by local residents. A recent study published by the Northwestern Colorado Council of Governments titled *Water and Economies of Headwaters Counties* (Coley and Forrest, Inc., 2012) credited boating-based activities with $1.1 million in total economic impacts in Pitkin County alone. According to this report, seven Colorado River Watershed headwaters counties (including Pitkin County) generate a combined $180 million each year from fishing-related activities. This study also recognized proximity to healthy natural settings and wildlife as an important and extremely valuable but un-quantified (in economic terms) characteristic of the region. Local communities receive numerous goods and services from functioning natural systems including clean drinking water, increased natural storage

and flood attenuation provided by intact floodplains and riparian zones, and viable wildlife communities upon which industries like fishing and recreation depend. Thus changes in the functional characteristics of local streams and rivers may portend shifts in the quality-of-life enjoyed by local residents and in the economic foundations supporting many local communities.



Dewatered section of the Crystal River above the Town of Carbondale. Without much flow, these segments experienced rapid heat gain during late summer and fall days.

The importance of instream flows to local economies and biological communities is increasingly recognized. The Roaring Fork Conservancy, with support from Pitkin County, recently published a study of water conservation options intended to enhance instream flows (Driscoll, 2012). The Colorado Water Trust launched an intensive effort to utilize short term leasing for water rights in 2012, a power authorized by the state legislature in response to a severe drought in 2002. To date, no leases in either the Crystal or Upper Roaring Fork have been utilized, but potential exists for this policy instrument to aid streamflows. Pitkin County recently engaged the use of creative and innovative policy instruments to increase instream flows in the Roaring Fork River by entering into a trust agreement to utilize water from the Stapleton Brothers Ditch for instream flows on lower Maroon Creek and the Roaring Fork. More agreements like these may be beneficial in the future to bolster flows on other stream reaches in the Roaring Fork Watershed. The data and analysis provided in this report can support future efforts to identify, evaluate, and execute action plans targeting water conservation improvements.

It is unclear to what extent low streamflow issues in the Crystal River and Roaring Fork River can be solved. Leasing programs show promise to benefit instream flows, but can add yet another layer of complexity to an already-complicated framework for resource management. Additionally, climate change brings uncertain impacts to precipitation and long-term basin yields in Colorado and the southern Rockies. Colorado's Climate Action Plan (Ritter, 2007) identified earlier thaw and snowmelt, and lower late summer and fall stream flows, as likely effects on the State's watersheds. In short: Colorado may

experience many more years exhibiting low flow conditions like those observed in 2002 and 2012. It is hoped that information from this assessment helps to empower intelligent decision-making regarding the area's water resources. If the cultural, economic, and environmental values surrounding these river systems are worthy of preserving, these pressing water issues should be proactively addressed.

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Appendix A:

Data Summary

The following tables summarize the streamflow, temperature, and specific conductance measurements collected on the Roaring Fork and Crystal Rivers during this study. Streamflow (Q) measurements were made using a Sontek FlowTracker® according to the USGS methods described by Turnipseed and Sauer (2010). Temperature and specific conductance measurements were made using a handheld Extech II © digital multimeter placed in the thalweg until readings stabilized.

Table 1. Roaring Fork study reach, streamflow data summary

Site Description	Pilot Study			Run 1			Run 2			Run 3		
	Date	Time	Q (cfs)	Date	Time	Q (cfs)	Date	Time	Q (cfs)	Date	Time	Q (cfs)
Above Difficult Creek	7/25	8:00	11	9/5	12:00	24	9/18	12:00	26	10/16	12:00	29
Above Salvation Ditch	7/25	8:00	25	9/5	12:00	31	9/18	12:00	32	10/16	12:00	38
At Aspen Club	7/25	9:00	7.6	9/5	16:00	24	9/18	15:30	18	10/16	15:45	34
At Mill Street Bridge	7/27	6:15	4.7	9/6	12:15	17	9/18	13:30	19	10/16	14:30	26
At Aspen Institute	7/25	13:45	18	9/6	10:30	21	9/18	11:30	28	10/16	13:00	44
At Stein Park	7/25	15:15	71	9/5	18:30	60	9/18	9:00	55	10/16	11:30	90
At CoA WWTP	7/25	8:00	147	9/5	12:00	112	9/18	10:00	108	10/16	12:00	134

Table 2. Crystal River study reach, streamflow data summary

Site Description	Run 1			Run 2			Run 3		
	Date	Time	Q (cfs)	Date	Time	Q (cfs)	Date	Time	Q (cfs)
Above Avalanche Creek	9/4	12:00	63	9/22	12:00	53	10/20	12:00	53
Above Sweet Jessup Canal	9/4	17:00	77	9/22	7:00	68	10/20	8:30	66
At Red Wind Point Open Space	9/4	15:00	59	9/22	8:30	58	10/20	9:45	61
Above Nettle Creek Road	9/5	8:30	29	9/22	10:00	26	10/20	10:30	38
Below Bane & Thomas Ditch	9/5	10:00	29	9/22	12:45	28	10/20	11:15	32
Above Lowline Ditch	9/4	13:00	31	9/22	14:00	24	10/20	12:30	32
At Pitkin Co. open space	9/4	11:00	24	9/22	15:15	7	10/20	1:45	30
At Thomas Road	9/4	9:30	4	9/22	17:00	1	10/20	2:00	28
Above County Line	9/4	8:00	12	9/23	7:30	8	10/20	3:15	33
At Fish Hatchery	9/3	12:00	14	9/23	12:00	8	10/21	12:00	42
At South Bridge in RVR	9/3	19:30	33	9/23	10:30	24	10/20	4:30	62
At North Bridge in RVR	9/3	17:30	36	9/23	9:00	21	10/20	5:45	69
Above Kaiser-Sievers Ditch	9/3	15:00	44	9/23	12:00	31	10/21	8:00	70
At CRMS Bridge	9/3	13:30	28	9/23	13:00	22	10/21	9:15	56

Table 3. Temperature data summary

Afternoon Stream Temperatures, (°F)							
Roaring Fork	**9/9**	**9/23**	**10/31**	**Crystal**	**9/7**	**9/21**	**11/1**
North Star, Upper	56	47	39	USGS Gauge above Avalanche Creek	62	53	41
North Star, Stillwater	56	48	38	USFS Boundary above Sweet Jessup Canal	63	53	42
Aspen Club	57	49	39	Red Wind Point Open Space	62	54	42
Neale Ave	59	50	41	Above Nettle Creek Road	63	55	43
Mill Street	60	51	42	Below Bane & Thomas Ditch	63	56	43
Aspen Institute	61	53	44	Above Lowline Ditch	65	58	44
Above Castle Creek	62	53	44	Thompson Creek Open Space	67	62	45
Below Castle Creek	59	51	44	Thomas Road	71	66	46
Cemetery Lane	59	51	44	Pitkin-Garfield County Line	67	63	47
Above Maroon Creek	59	51	44	DWR Gauge Fish Hatcher	65	62	48
Below Maroon Creek	58	51	43	RVR South Bridge	63	62	49
Airport Business Park	58	51	43	RVR North Bridge	67	65	51
				Kaiser & Sievers Ditch	68	65	50
				CRMS Bridge	69	66	50
				Confluence w/ Roaring Fork	68	66	51

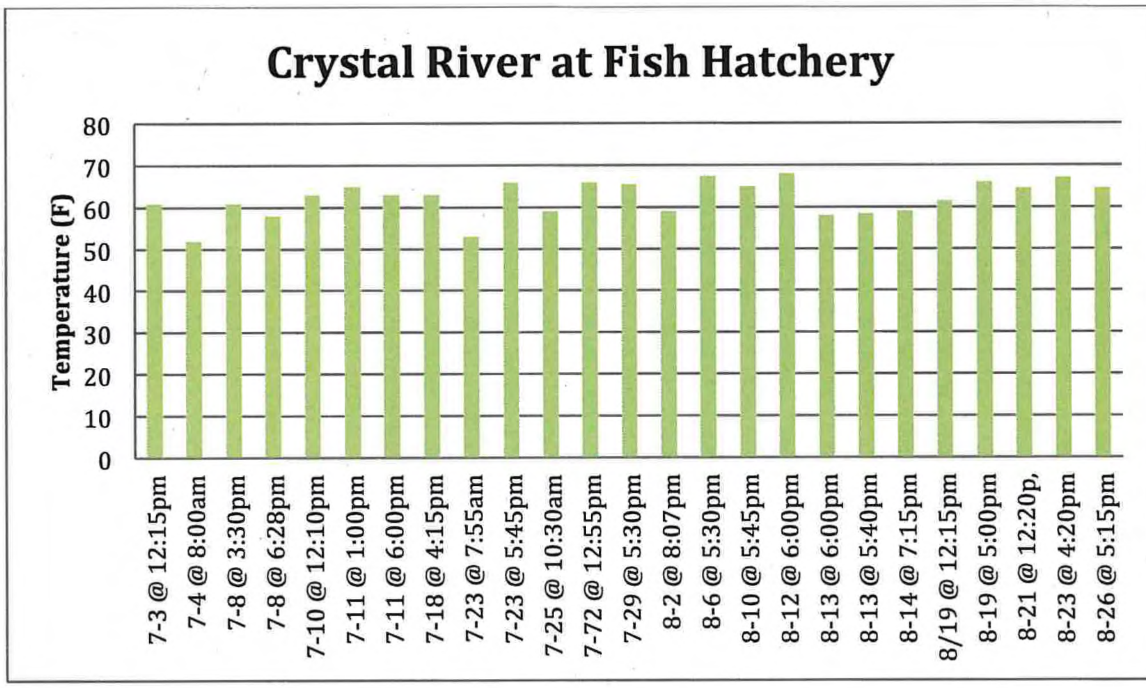
Table 4. Specific conductance data summary

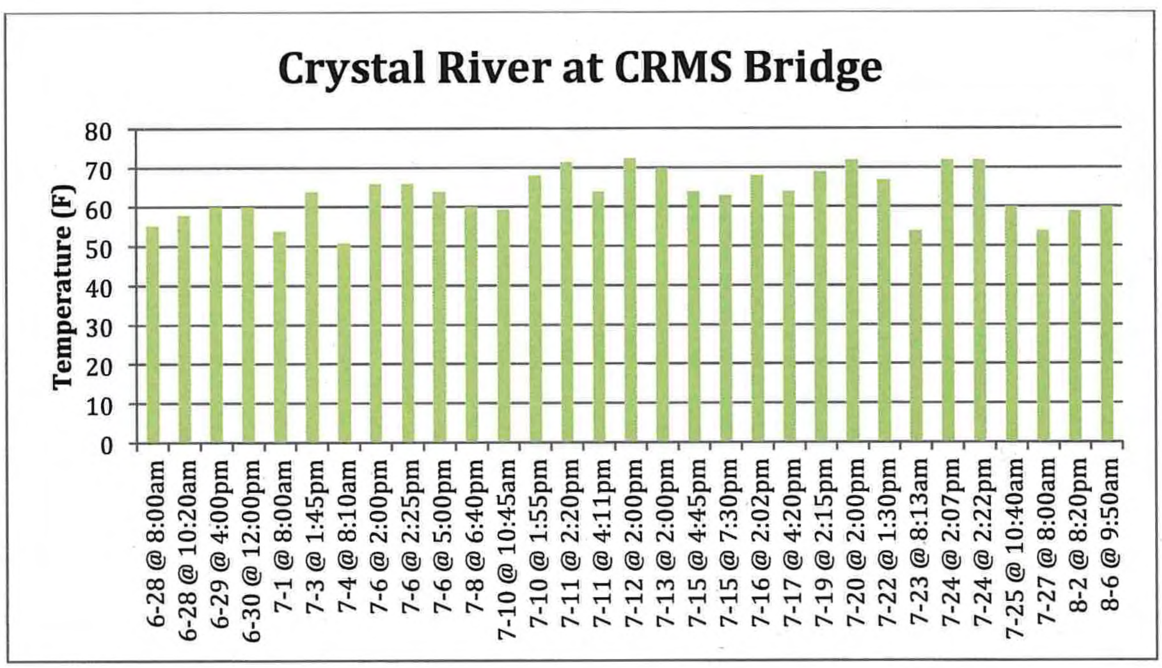
Specific Specific conductance (µS/cm)							
Roaring Fork	**9/9**	**9/23**	**10/31**	**Crystal**	**9/9**	**9/21**	**11/1**
North Star, Upper	96	92	90.7	USGS Gauge above Avalanche Creek	582	607	696
North Star, Stillwater	96	90	84.8	USFS Boundary above Sweet Jessup Canal	581	596	679
Aspen Club	96	95	88	Red Wind Point Open Space	584	603	681
Neale Ave	104	106	96.7	Above Nettle Creek Road	587	603	677
Mill Street	111	127	119	Below Bane & Thomas Ditch	563	597	660
Aspen Institute	198	215	184	Above Lowline Ditch	564	610	655
Above Castle Creek	215	236	199	Thompson Creek Open Space	558	587	619
Below Castle Creek	325	333	282	Thomas Road	548	563	637
Cemetery Lane	361	382	366	Pitkin-Garfield County Line	520	521	627
Above Maroon Creek	366	387	367	DWR Gauge Fish Hatcher	556	567	636
Below Maroon Creek	397	422	405	RVR South Bridge	593	600	638
Airport Business Park	419	445	436	RVR North Bridge	572	585	627
				Kaiser & Sievers Ditch	616	639	646
				CRMS Bridge	609	621	643
				Confluence w/ Roaring Fork	618	615	649

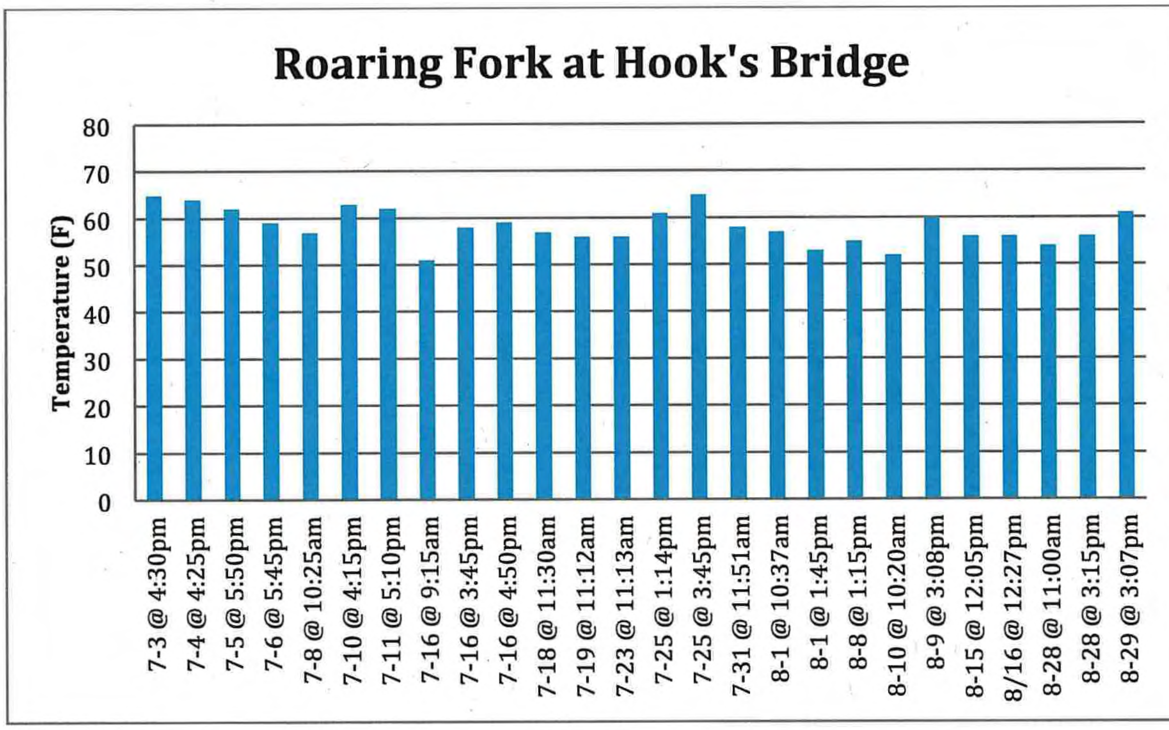
Appendix B:

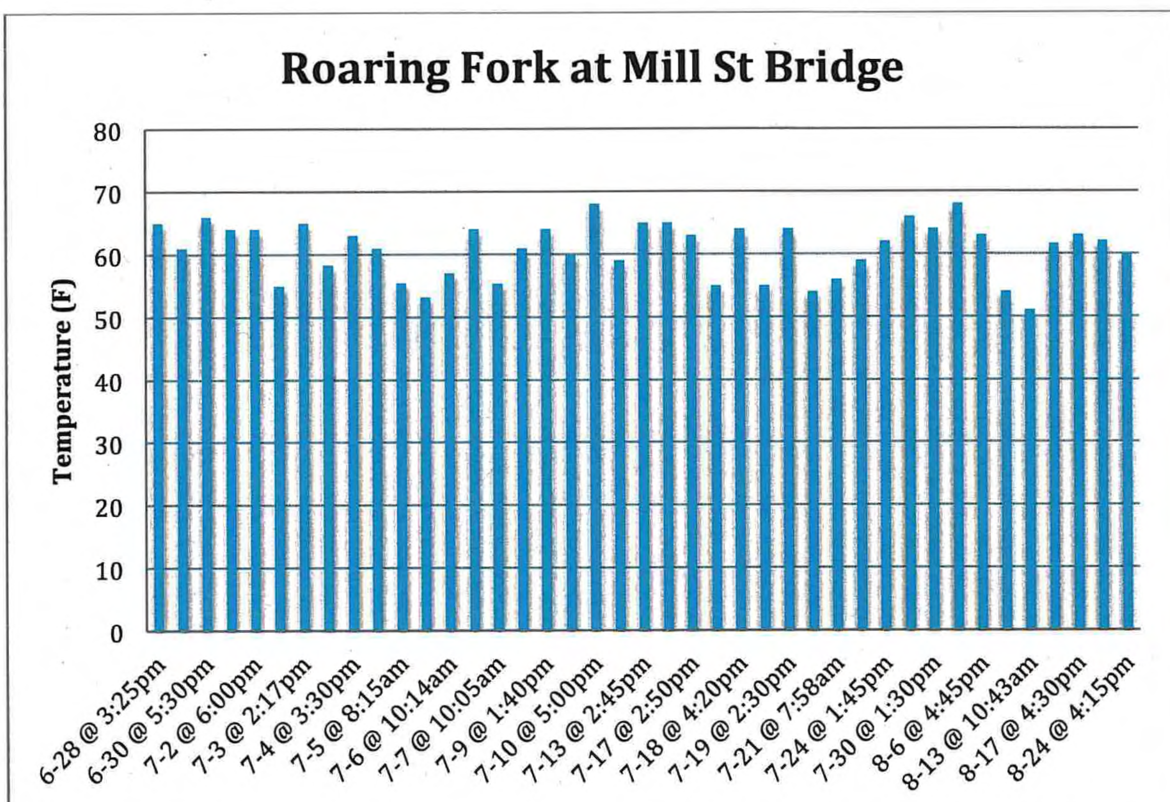
Roaring Fork Conservancy's *Hot Spots for Trout* Data

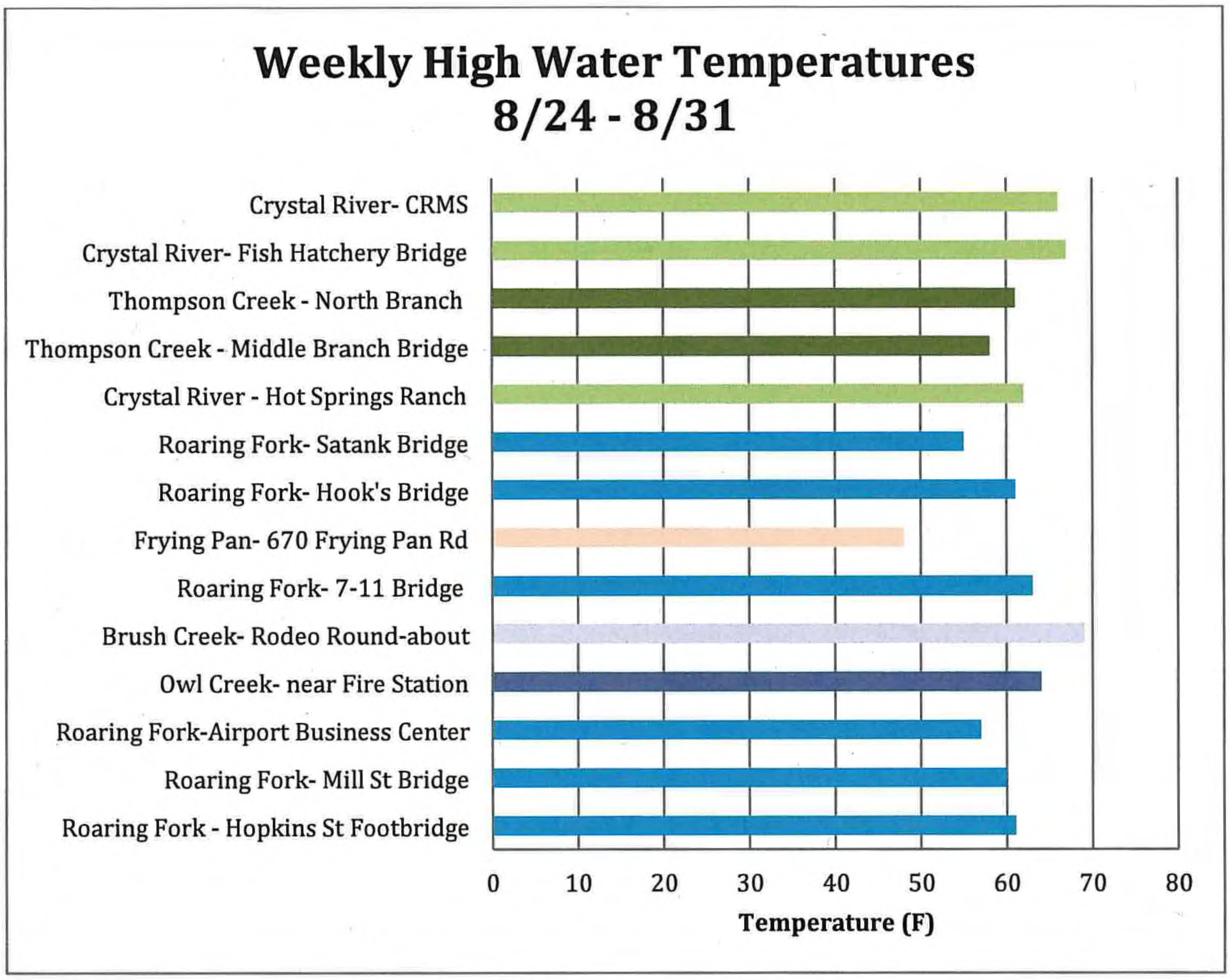
Figures provided by the Roaring Fork Conservancy. For more information see:
http://roaringfork.org



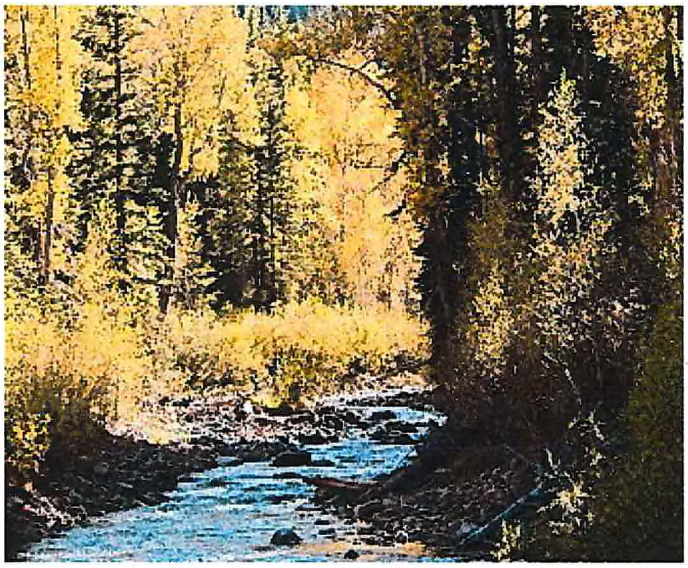



Roaring Fork at Hook's Bridge
Temperature (F)
0
10
20
30
40
50
60
70
80
7-3 @ 4:30pm
7-4 @ 4:25pm
7-5 @ 5:50pm
7-6 @ 5:45pm
7-8 @ 10:25am
7-10 @ 4:15pm
7-11 @ 5:10pm
7-16 @ 9:15am
7-16 @ 3:45pm
7-16 @ 4:50pm
7-18 @ 11:30am
7-19 @ 11:12am
7-23 @ 11:13am
7-25 @ 1:14pm
7-25 @ 3:45pm
7-31 @ 11:51am
8-1 @ 10:37am
8-1 @ 1:45pm
8-8 @ 1:15pm
8-10 @ 10:20am
8-9 @ 3:08pm
8-15 @ 12:05pm
8/16 @ 12:27pm
8-28 @ 11:00am
8-28 @ 3:15pm
8-29 @ 3:07pm


Roaring Fork at Mill St Bridge
Temperature (F)
0
10
20
30
40
50
60
70
80
6-28 @ 3:25pm
6-30 @ 5:30pm
7-2 @ 6:00pm
7-3 @ 2:17pm
7-4 @ 3:30pm
7-5 @ 8:15am
7-6 @ 10:14am
7-7 @ 10:05am
7-9 @ 1:40pm
7-10 @ 5:00pm
7-13 @ 2:45pm
7-17 @ 2:50pm
7-18 @ 4:20pm
7-19 @ 2:30pm
7-21 @ 7:58am
7-24 @ 1:45pm
7-30 @ 1:30pm
8-6 @ 4:45pm
8-13 @ 10:43am
8-17 @ 4:30pm
8-24 @ 4:15pm


Weekly High Water Temperatures
8/24 - 8/31
Crystal River- CRMS
Crystal River- Fish Hatchery Bridge
Thompson Creek - North Branch
Thompson Creek - Middle Branch Bridge
Crystal River - Hot Springs Ranch
Roaring Fork- Satank Bridge
Roaring Fork- Hook's Bridge
Frying Pan- 670 Frying Pan Rd
Roaring Fork- 7-11 Bridge
Brush Creek- Rodeo Round-about
Owl Creek- near Fire Station
Roaring Fork-Airport Business Center
Roaring Fork- Mill St Bridge
Roaring Fork - Hopkins St Footbridge
0
10
20
30
40
50
60
70
80
Temperature (F)

The Future of Instream Flows in Snowmass Creek



Prepared for the
Snowmass/Capitol Creek Caucus

September 2012

amec

Table of Contents

List of Figures

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In your document, select the words to include in the table of contents, and then in the Formatting Palette under Styles, click a heading style. Repeat for each heading that you want to include, and then insert the table of contents in your document. You can also create a table of contents by clicking the Create with Manual Formatting option and then type the entries manually.

List of Tables

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List of Attachments

1 Executive Summary

The Snowmass Capitol Creek Caucus ("Caucus") commissioned this AMEC study in order to assess, and to mitigate in collaboration with the Snowmass Water and Sanitation District ("District"), the impacts of future water demands upon healthy and sustainable flows in Snowmass Creek. For over thirty years, the Caucus has maintained an active interest in protecting Snowmass Creek, especially during critical low-flow months when municipal demands are high in the adjacent Brush Creek Basin where the Town of Snowmass Village and the Snowmass Ski Area depend almost exclusively on East Snowmass and Snowmass Creek water.

The Caucus is committed to securing flows necessary to meet the Colorado Water Conservation Board's biologically-based minimum "stair step" instream flow right in the Middle Reach of Snowmass Creek year-round. To this end, the Caucus has actively supported the District's development of Zeigler Reservoir as well as the District's very significant achievements in water loss control and water conservation in recent years.[1]

The Caucus likewise is committed to working cooperatively with the District to insure that wise water management practices are implemented and monitored in both the Brush Creek and Snowmass Creek basins since the users in each basin rely on one creek, Snowmass Creek, for their water needs. AMEC's assumptions, analyses and recommendations are furnished to assist the Caucus and the District in adopting and employing water infrastructure and water management programs that protect and conserve adequate stream flows in Snowmass Creek.

WATER NEEDED TO PROTECT SNOWMASS CREEK

The CWCB's "stair step" instream flow right for the Middle Reach of Snowmass Creek represents a scientifically derived expression of the instream regime needed to protect the natural environment of the Middle Reach of Snowmass Creek. It is responsive to variations in natural flow patterns, and while it specifies lower flows in dry year, it also requires higher flows in wetter years and in years following extended multi-year dry periods in order to prevent degradation of the aquatic habitat and fish populations. The CWCB stair step right should be the standard of protection for the Middle Reach of Snowmass Creek.

The minimum flow needed to protect Snowmass Creek's aquatic ecosystems and trout populations has been the subject of much study. After extensive study and input from stakeholders, the Colorado Water Conservation Board (CWCB) modified its instream

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[1] AMEC (then Hydrosphere) was engaged by the Caucus to first analyze the benefits of raw water storage in 2005 resulting in a report recommending at least 100 acre feet of storage (Hydrosphere Resource Consultants, Inc., Water Availability for Snowmass Base Village Development, June 20, 2005).

flow right for the Middle Reach of Snowmass Creek (hereafter the "CWCB stair step right") to include a fixed flow of 15 cfs during the spring and summer and a variable flow during the fall and winter based on the average stream flow during the preceding October 11 – October 15 that acts as a "trigger". The variable portion of the instream flow right is specified as one of four "stair step" flow schedules that correspond to a flow trigger that falls within the following statistical categories: 50th percentile or greater, between 25th and 50th percentile, between 10th and 25th percentile, or below 10th percentile. The CWCB stair step right provides additional protection after prolonged drought: following three consecutive "less than 10th percentile" years, the CWCB stair step right specifies a "recovery year" at the "50th percentile or greater" stair step flow schedule, regardless of the flow trigger.

INCREASING WATER DEMANDS

Water demands from Snowmass Creek will foreseeably increase. Additional development within the District's service area is expected to increase the number of customers within the District from 5,181 equivalent residential units (EQRs) to 6,107 EQRs. At current per EQR water use levels, the District's water demands are expected to increase from 1,480 acre-feet per year to 1,806 acre-feet per year at build-out, an increase of 22%, as shown in Table 4. In addition, snowmaking water demands for the Snowmass ski area could increase by 25% from a current average of 217 acre-feet per year to more than 270 acre-feet per year under terms of the ski area's U.S. Forest Service permit.

SCENARIO ANALYSIS

We evaluated the District's diversions from Snowmass Creek at existing and projected build-out demand levels using a 41-year period of hydrologic record (1970-2010). We included in our analysis an example climate change scenario. Climate change is expected to significantly alter the typical stream flow pattern in Snowmass Creek, resulting in earlier runoff and reduced stream flows in the late summer, fall and mid winter, as shown in Figure 25.

We analyzed 16 supply/demand scenarios. The results of our analysis are summarized in Table 11 of this report. The frequency and magnitudes of shortages to the CWCB stair step right for each of these scenarios are portrayed in Tables 12 through 37. These scenarios were analyzed against the CWCB stair step right to ascertain when, how often, and how severely water supply would be insufficient to supply this protective minimum instream flow standard.

NATURAL FLOW CONDITIONS

These results indicate that shortages to the CWCB stair step right for the Middle Reach of Snowmass Creek will occasionally occur even under natural conditions. However,

shortages will occur infrequently (1.7% of the days) and will be relatively minor (averaging 10% of the specified minimum flow).

DISTRICT'S EXISTING DEMANDS, NO INSTREAM FLOW BUFFERING

At the District's current demand levels and if Ziegler Reservoir is not used to buffer instream flows, the District's diversions will significantly increase the frequency and magnitude of instream flow shortages compared to the natural flow condition, particularly during January through April in extended dry periods, although the District's water loss control and water conservation efforts have significantly reduced the District's depletive 'footprint' on Snowmass Creek.

DISTRICT'S BUILD OUT DEMANDS, NO INSTREAM FLOW BUFFERING

At projected build-out demand levels and if Ziegler Reservoir is not used to buffer instream flows, the District's diversions will further increase the frequency and magnitude of instream flow shortages compared to the natural flow condition. Even with the additional water conservation savings that are likely to result from the District's water conservation plan and full use of the District's Brush Creek supplies, the frequency and magnitude of instream flow shortages will increase significantly compared to existing demand conditions.

STRATEGIC MITIGATING ROLE OF ZIEGLER RESERVOIR

Ziegler Reservoir has the potential to greatly reduce the impacts of the District's diversions upon the CWCB stair step right. Given its multiple refill water right, the reservoir can be a very effective buffer for instream flows, supplying the District's needs and reducing the District's direct flow diversions during periods of inadequate stream flow, and refilling when stream flows are in excess of the CWCB stair step right.

The District's reservoir Operating Plan is well structured to allow the reservoir to operate in a manner that would provide nearly complete protection to the CWCB stair step right under both existing and build-out demand conditions while meeting the District's goals regarding water supply reliability and water quality, provided the reservoir is used to buffer the District's diversions from both East Snowmass Creek and Snowmass Creek. Buffering of diversions from East Snowmass Creek is necessary to achieve this benefit because the District typically satisfies most of its demands with its East Snowmass Creek diversions, and uses the Pump Station to meet its municipal demands relatively infrequently.

Under its Operating Plan, the District intends to partially draw down the reservoir during each non-irrigation season to maintain water quality in the reservoir. Using the reservoir to buffer stream flows when the District's diversions would otherwise reduce stream flows below the CWCB stair step right would be consistent with that purpose.

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Notably, the recent snowmaking agreement between the District and the Aspen Skiing Company provides significant additional access to water stored in Ziegler Resevoir for snowmaking, both before and after December 31st. This agreement could significantly diminish the effectiveness of Ziegler Reservoir to act as a buffer for instream flows in Snowmass Creek. The agreement appears to prohibit the District from withdrawing water from the reservoir to meet its municipal demands during the snowmaking season (October 15 through December 31) unless all of the District's other supplies are insufficient. This limitation would prohibit the District from withdrawing water from the reservoir to meet its municipal demands in order to satisfy the CWCB stair step right. There will be occasional times during the snowmaking season when flows in Snowmass Creek will be insufficient to supply the District's municipal demands on a direct flow basis without causing shortages to the CWCB stair step right. If the District can withdraw water from the reservoir to supply its municipal demands during such times, shortages to the CWCB stair step right would be significantly reduced without affecting the amount or reliability of snowmaking supply to the Skiing Company.

Another major concern regarding the Ziegler snowmaking agreement is the potential for snowmaking withdrawals from the reservoir during January 1 through March 15. This is the season when Ziegler reservoir is most needed to act as a buffer between the District's municipal diversions and the CWCB stair step right, particularly in dry years. While the Skiing Company has not historically taken snowmaking water after December, the Ziegler snowmaking agreement would allow snowmaking deliveries from Ziegler Reservoir from January 1 through March 15 under certain limitations. Any significant amount of snowmaking delivery from Ziegler Reservoir during January through March, particularly in dry years, would impair the District's ability to use Ziegler to buffer instream flows and is likely to result in additional shortages to instream flows because natural stream flows are generally at their lowest levels during these months.

CLIMATE CHANGE IMPACTS

Assuming climate change-driven natural flow hydrology, instream flow shortages will occur more frequently in the Middle Reach of Snowmass Creek even without the depletive effects of diversions. These "natural" shortages would occur more than twice as often as would occur under historical natural flow hydrology. With climate change, the CWCB stair step right for Snowmass Creek would be set to the lowest two levels of the stair step methodology in approximately 75% of the years. As a result, even small shortages to the CWCB stair step right would have serious consequences.

Even with climate change, Ziegler Reservoir has the potential to greatly reduce the impacts of the District's diversions upon the CWCB stair step right. Use of the reservoir to buffer instream flows would provide effective protection to instream flows except in occasional very dry years, when the reservoir would be drawn down to the reserve storage pool. Additional water conservation savings that are likely to result from the District's water conservation plan, along with the District's use of its Brush Creek

supplies (subject to raw water supply blending requirements), would further reduce the District's impacts to the CWCB stair step right.

MAINTENANCE OF THE CWCB STAIRSTEP RIGHT

As the District grows to build-out within its service area, the combination of using Ziegler Reservoir to buffer instream flows, continued efforts by the District to minimize water losses, full use of available supplies from Brush Creek, and increased water savings from the District's water conservation plan should allow the District to meet its build-out water demands without significantly impacting the CWCB stair step right. The key to this positive outcome would be the active use of Ziegler Reservoir to buffer instream flows during low flow periods. Even in the face of climate change, these four elements would greatly mitigate the District's effects on minimum stream flows in Snowmass Creek.

Greater concern exists regarding the potential effects of irrigation diversions under climate change conditions. The combination of increased per-acre irrigation demand and reduced stream flows in the summer months is likely to result in chronic and severe instream flow shortages in the lower portion of the Middle Reach of Snowmass Creek during July through September.

A coordinated effort by all irrigators diverting from Snowmass Creek to improve their irrigation efficiencies, coordinate their irrigation scheduling and practice rotational fallowing or deficit irrigation may be necessary to avoid major impacts to Snowmass Creek during dry years, assuming climate change.

RECOMMENDATIONS

In light of these conclusions, we recommend the following.

1. The District should adopt the CWCB stair step right as its stewardship goal for protection of Snowmass Creek.

2. The District should refine its Ziegler Reservoir operation plan to maximize the use of the reservoir to protect the CWCB stair step right on Snowmass Creek, consistent with the District's reserve storage requirement, snowmaking delivery obligations and reservoir water quality management goals. Specific suggestions for refining the Operating Plan are discussed in Section 8 of this report.

3. The District should work with the Skiing Company to eliminate any uncertainties regarding the District's ability to withdraw water from Ziegler reservoir during the snowmaking season to meet the District's municipal demands to the extent needed to satisfy the CWCB stair step right.

4. Regarding the use of Ziegler Reservoir from January 1 through March 15 of each year, the District should develop operating rules that give priority to the protection of the CWCB stair step right over snowmaking deliveries in years with below-average winter season flows.

5. The District should maintain its exemplary efforts in water loss control and should actively pursue the full implementation of its water conservation plan.

6. The District should divert and use available supplies from the West Fork of Brush Creek, subject to its 50%/50% source water blend requirement[2].

7. Given the likely effects of climate change, the Caucus should work with all irrigators who divert from Snowmass Creek to improve irrigation efficiencies, coordinate diversion scheduling, and develop a contingency plan that may involve rotational fallowing, deficit irrigation and wastewater reuse to ensure that shortages to the CWCB stair step right are avoided during July through September of critical dry periods.

We recommend that the Caucus engage the District, the Skiing Company and irrigators that divert from Snowmass Creek with these recommendations in mind. There are several forums and initiatives active in and around the County that may be relevant vehicles for involvement, including the Roaring Fork Conservancy, the Pitkin County Healthy Rivers and Streams Board, the Western Rivers institute and the Colorado River Basin Roundtable. Funds may be available from the State of Colorado or from Pitkin County Healthy Rivers and Streams to defray the costs for additional study of these alternatives and/or construction of any needed facilities.

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[2] According to information provided by the District, raw water diverted from the West Fork of Brush Creek must be blended at least a 50%/50 ratio with raw water from Snowmass Creek or East Snowmass Creek to address water quality concerns.

AGENDA ITEM SUMMARY

February 21, 2013

TO: River Board

FROM: Lisa MacDonald

SUBJECT: Scope of Work for Request for Proposals Interactive Mapping Project

Information: At the January 17th meeting, the River Board authorized Zach Purdue to draft a scope of work for a request for proposals for an interactive web based mapping program. Attached for your review is the drafted scope of work.

Requested Board Action: Approve scope of work and direct staff to move forward with the RFP process.

Attachments: Draft Scope of Work

INTRODUCTION

Pitkin County is seeking proposals from qualified firms/individuals to perform spatial analysis, cartography, graphic design, web development and internet mapping services as it relates to a public outreach campaign.

The purpose of the County's public outreach is to visually depict to the general public how current water diversion structures, associated tributaries, and other contributing factors, impact streamflow conditions and overall stream health on defined stretches of both the Roaring Fork and Crystal Rivers within the broader Roaring Fork Watershed. Currently, both rivers are encumbered by a number of complex issues that threaten stream health, including reduced streamflow resulting from active diversion structures, loss of riparian habitat and floodplain due to development and urbanization, reduced quality of fisheries, and potential water quality impairment. The project should employ scientifically credible data to inform discussions with water right holders and local communities, as well as communicate to the public the status and integrity of river health within the Roaring Fork and Crystal River watersheds as it relates to streamflow depletion.

All spatial data will be acquired, analyzed and produced within a GIS. All baseline spatial data and analysis results will be presented as informed and easily interpreted graphical products that may include, but are not limited to: hard-copy map(s), graph(s), table(s), infographic(s), and/or internet mapping. All product deliverables will be hosted and served to the public via the Pitkin County Healthy Rivers and Streams website.

Spatial analysis may include, but is not limited to, determining historic natural condition streamflows and river health, forecasting future streamflows and river health, and understanding current natural condition streamflows, including impacts to flows and river health that result from depletions of active diversion structures.

All product deliverables shall present the results of the analysis and other pertinent baseline data in high quality graphical visual representations that present and summarize all relevant information quickly and clearly.

SCOPE OF WORK

The Scope of Work may include, but is not limited to:

1. **Data Review, Acquisition and Production:** The contractor will be responsible for acquiring and reviewing for accuracy and relevancy all data sources employed in the project. All data sources must be cited accordingly to their respective use.
2. **Spatial Analysis and Modeling:** The contractor will be responsible for devising a method for, as well as executing, all spatial analysis and modeling as it pertains to achieving the objectives of the project. All spatial data and project files will be stored and provided to Pitkin County in a Personal or File Geodatabase compliant with the ESRI ArcGIS 10.0 software platform.

3. **Development of Product Deliverables:** All project analyses, baseline conditions, modeled conditions and other associated data and information must be depicted in high quality graphical visual representations meant to inform and engage the viewer.
4. **Web Development:** All project information, descriptions, reports, summaries and graphical visual representations will be hosted and served to the public via the Pitkin County Healthy Rivers and Streams website. Contractor will be responsible for developing the individual web pages required to host the identified content in a framework and format consistent with the existing Healthy Rivers and Streams website.
5. **Internet Mapping System Development:** The contractor will be responsible for developing and deploying an Internet Mapping System to serve and display all relevant project spatial data, analyses results, textual information and other rich media formats (e.g. photos, videos, etc.). Contractor will be required to host and serve all spatial data and deliver through the Pitkin County Healthy Rivers and Streams website.

SUBMISSION REQUIREMENTS

A proposal must contain the following, **referenced by number and in the order below:**

1. **Cover Letter:** Summarize the proposal, including name, firm affiliation (if any), address and all relevant contact information (e.g. telephone, facsimile, email, website address, etc.).
2. **Contact:** Provide the name, address, telephone number and email for the primary contact of the company/organization, along with a brief description of the services provided.
3. **Qualifications:** A statement of qualifications of all involved individuals and firm (if any) including background and experience.
4. **Related Experience:** Provide details of associated consulting work previously performed for Pitkin County and other clients.
5. **Individual Description:** A description of what is distinctive about you and your firm (if any) and the services offered.
6. **Familiarity with Aspen and Pitkin County Community:** Describe work completed for local/regional entities for whom you have previously provided consulting services.
7. **Proposed Methodology and Product Deliverables:** A detailed description of the proposed methods you intend to employ in executing the project, including techniques, methods and data sources. List and describe all end product(s) that would be developed and produced to display the project information and analysis.
8. **Costs and Payment Method:** State the total costs for performing all projected-related tasks and activities, as well as the proposed method of compensation for services rendered.
9. **Subcontractors:** List any subcontractors intended to be used in the project.
10. **Professional References:** Provide a minimum of three (3) professional references or prior clients, especially government agencies or entities.
11. **Public Projects:** Provide three (3) examples of work with governmental and/or non-profit agencies within the past three (3) years. Discuss the relative "success" of the project. Please include the contact person and phone number for each entity.

AGENDA ITEM SUMMARY

February 21, 2013

TO: River Board

FROM: Lisa MacDonald

SUBJECT: Letter of Support RWAPA

Information: We have received a request for a letter of support from Ruedi Water and Power Authority for the Ruedi Reservoir Invasive Species Inspection Program and the Boat Colorado grant application

Requested Board Action: Motion to authorize the Chairman to sign the letter on behalf of the Board for the Ruedi Reservoir Invasive Species Inspection Program and the Boat Colorado grant application.

Attachments: Draft Letter of Support

February 22, 2013

To Whom it May Concern:

This is to express the support of the Pitkin County Healthy Rivers and Streams Board ("PCHRSB") for the Ruedi Reservoir Invasive Species Inspection Program and the "Boat Colorado" grant application. PCHRSB has contributed to this program in the past in the form of donated funds, services, equipment, or administrative support. We believe that it is an important to keep Ruedi free of invasive species and we applaud the Ruedi Water and Power Authority (RWAPA) for taking the initiative to provide these inspection services.

This will be the fourth year that RWAPA has managed the inspection program and we are satisfied that the program is in good hands. We know that this program has provided valuable education to boaters while it has safeguarded an important local recreational and environmental resource. Since 2012 we have been able to depend on the RWAPA program to keep Ruedi free of invasive species and we would like to see that program continued as long as the threat of endangered species continues.

We support their grant request to the "Boat Colorado" program and we urge you to approve this request.

Sincerely,

Bill Jochems
Chairman